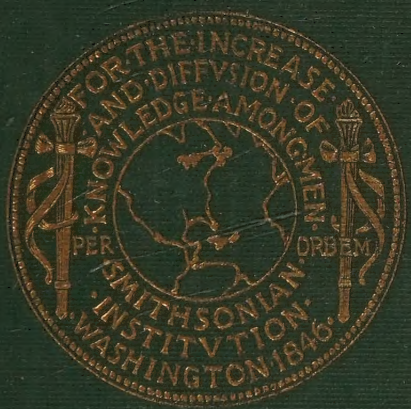
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ANNUAL REPORT OF THE BOARD OF REGENTS OF

THE SMITHSONIAN INSTITUTION

SHOWING THE

OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION FOR THE YEAR ENDING JUNE 30

1922

(Publication 2724)

WASHINGTON
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1924

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LETTER

FROM THE

ACTING SECRETARY OF THE SMITHSONIAN INSTITUTION

SUBMITTING

THE ANNUAL REPORT OF THE BOARD OF REGENTS OF THE INSTITUTION FOR THE YEAR ENDING JUNE 30, 1922.

SMITHSONIAN INSTITUTION,
Washington, July 15, 1923.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1922. I have the honor to be,

Very respectfully, your obedient servant,

C. G. ABBOT,
Acting Secretary.

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ANNUAL REPORT OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1922.

SUBJECTS.

1. Annual report of the secretary, giving an account of the operations and condition of the Institution for the year ending June 30, 1922, with statistics of exchanges, etc.

2. Report of the executive committee of the Board of Regents, exhibiting the financial affairs of the Institution, including a statement of the Smithsonian fund, and receipts and expenditures for the year ending June 30, 1922.

3. Proceedings of the Board of Regents for the fiscal year ending June 30, 1922.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1922.

THE SMITHSONIAN INSTITUTION.

June 30, 1922.

Presiding officer ex officio.—WARREN G. HARDING, President of the United States.
Chancellor.—CALVIN COOLIDGE, Vice President of the United States.
Members of the Institution:

WARREN G. HARDING, President of the United States.
CALVIN COOLIDGE, Vice President of the United States.
WILLIAM HOWARD TAFT, Chief Justice of the United States.
CHARLES EVANS HUGHES, Secretary of State.
ANDREW W. MELLON, Secretary of the Treasury.
JOHN WINGATE WEEKS, Secretary of War.
HARRY M. DAUGHERTY, Attorney General.
HUBERT WORK, Postmaster General.
EDWIN DENBY, Secretary of the Navy.
ALBERT BACON FALL, Secretary of the Interior.
HENRY CANTWELL WALLACE, Secretary of Agriculture.
HERBERT CLARK HOOVER, Secretary of Commerce.
JAMES JOHN DAVIS, Secretary of Labor.

Regents of the Institution:

CALVIN COOLIDGE, Vice President of the United States, Chancellor.
WILLIAM HOWARD TAFT, Chief Justice of the United States.
HENRY CABOT LODGE, Member of the Senate.
A. OWSLEY STANLEY, Member of the Senate.
MEDILL MCCORMICK, Member of the Senate.
LEMUEL P. PADGETT, Member of the House of Representatives.
FRANK L. GREENE, Member of the House of Representatives.
ALBERT JOHNSON, Member of the House of Representatives.
GEORGE GRAY, citizen of Delaware.
CHARLES F. CHOATE, Jr., citizen of Massachusetts.
JOHN B. HENDERSON, citizen of Washington, D. C.
HENRY WHITE, citizen of Maryland.
ROBERT S. BROOKINGS, citizen of Missouri.

Executive committee.—GEORGE GRAY, HENRY WHITE, JOHN B. HENDERSON.
Secretary of the Institution.—CHARLES D. WALCOTT.
Assistant Secretary.—C. G. ABBOT.
Chief Clerk.—HARRY W. DORSEY.
Accounting and disbursing agent.—W. I. ADAMS.
Editor.—W. P. TRUE.
Assistant librarian.—PAUL BROCKETT
Property clerk.—J. H. HILL.

THE NATIONAL MUSEUM.

Keeper ex officio.—Charles D. Walcott, Secretary of the Smithsonian Institution.

Administrative assistant to the Secretary, in charge.—W. de C. Ravenel.

Head curators.—Walter Hough (Acting), Leonhard Stejneger, G. P. Merrill.

Curators.—Paul Bartsch, R. S. Bassler, T. T. Belote, Austin H. Clark, F. W. Clarke, F. V. Coville, W. H. Dall, Walter Hough, L. O. Howard, Aleš Hrdlička, Neil M. Judd, Frederick L. Lewton, George P. Merrill, Gerrit S. Miller, Jr., Carl W. Mitman, Robert Ridgway, Waldo L. Schmitt, Leonhard Stejneger.

Associate curators.—J. M. Aldrich, C. W. Gilmore, W. R. Maxon, Charles W. Richmond, J. N. Rose, David White.

Chief of correspondence and documents.—H. S. Bryant.

Disbursing agent.—W. I. Adams.

Superintendent of buildings and labor.—J. S. Goldsmith.

Editor.—Marcus Benjamin.

Assistant librarian.—N. P. Scudder.

Photographer.—Arthur J. Olmsted.

Property clerk.—W. A. Knowles.

Engineer.—C. R. Denmark.

Shipper.—L. E. Perry.

NATIONAL GALLERY OF ART.

Director.—William H. Holmes.

FREER GALLERY OF ART.

Curator.—John Ellerton Lodge.

Associate curator.—Carl Whiting Bishop.

Assistant curator.—Grace Dunham Guest.

Associate.—Katharine Nash Rhoades.

Superintendent.—John Bundy.

BUREAU OF AMERICAN ETHNOLOGY.

Chief.—J. Walter Fewkes.

Ethnologists.—John P. Harrington, J. N. B. Hewitt, Francis La Flesche, Truman Michelson, John R. Swanton.

Editor.—Stanley Searles.

Librarian.—Ella Leary.

Illustrator.—De Lancey Gill.

INTERNATIONAL EXCHANGES.

Chief Clerk.—C. W. Shoemaker.

NATIONAL ZOOLOGICAL PARK.

Superintendent.—Ned Hollister.

Assistant Superintendent.—A. B. Baker.

ASTROPHYSICAL OBSERVATORY.

Director.—C. G. Abbot.

Aid.—F. E. Fowle, Jr.

Assistant.—L. B. Aldrich.

REGIONAL BUREAU FOR THE UNITED STATES, INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

Assistant in charge.—Leonard C. Gunnell.

REPORT

OF THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

CHARLES D. WALCOTT,

FOR THE YEAR ENDING JUNE 30, 1922.

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor to submit herewith the annual report of the activities and condition of the Smithsonian Institution and its branches during the year ending June 30, 1922. The affairs of the Institution proper (together with brief summaries of the operations of the various branches) are given on pages 1 to 25 of this report, and the appendixes contain somewhat detailed accounts of the year's work, written by the head of each of the branches. These include reports on the United States National Museum, the National Gallery of Art, the Freer Gallery of Art, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, the United States Regional Bureau of the International Catalogue of Scientific Literature, the Smithsonian Library, and the publications of the Institution and its branches.

THE SMITHSONIAN INSTITUTION.

THE ESTABLISHMENT.

The Smithsonian Institution was created by act of Congress in 1846, according to the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust Congress determined that the Federal Government was without authority to administer the trust directly, and therefore constituted an "establishment" whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS.

The affairs of the Institution are administered by a Board of Regents whose membership consists of "the Vice President, the Chief Justice, three Members of the Senate, and three Members of the House of Representatives, together with six other persons other than Members of Congress, two of whom shall be resident in the city of Washington and the other four shall be inhabitants of some State, but no two of them of the same State." One of the Regents is elected chancellor by the board; in the past the selection has fallen upon the Vice President or the Chief Justice; and a suitable person is chosen by them as secretary of the Institution, who is also secretary of the Board of Regents and the executive officer directly in charge of the Institution's activities.

In regard to the personnel of the board, the following changes occurred during the year: Chief Justice William H. Taft became a member of the board by virtue of his office; Representative Albert Johnson, of the State of Washington, was appointed to succeed Representative John A. Elston, who died during the year; and Dr. Alexander Graham Bell retired from the board at the expiration of his term.

The roll of the Regents at the close of the fiscal year was as follows: Calvin Coolidge, Vice President of the United States, chancellor; Chief Justice William H. Taft; Henry Cabot Lodge, Member of the Senate; A. Owsley Stanley, Member of the Senate; Medill McCormick, Member of the Senate; Lemuel P. Padgett, Member of the House of Representatives; Frank L. Greene, Member of the House of Representatives; Albert Johnson, Member of the House of Representatives; George Gray, citizen of Delaware; Charles F. Choate, jr., citizen of Massachusetts; John B. Henderson, citizen of Washington, D. C.; Henry White, citizen of Washington, D. C., and Robert S. Brookings, citizen of Missouri.

The board held its annual meeting on December 8, 1921. The proceedings of that meeting, as well as the annual financial report of the executive committee, have been printed as usual for the use of the Regents, while such important matters acted upon as are of public interest are reviewed under appropriate heads in the present report of the secretary. A detailed description of disbursements from the Government appropriations under the direction of the Institution for the maintenance of the National Museum, the National Zoological Park, and other branches will be submitted to Congress by the secretary in the usual manner in accordance with the law.

GENERAL CONSIDERATIONS.

Desiring to increase the research output of the Institution, your secretary called a meeting in May of this year of the scientific staff of the Institution and its branches to consider ways and means

of inaugurating and carrying out a program of more extensive original research. At this meeting a committee on research was named, with Dr. George P. Merrill, head curator of geology, as chairman, which will consider the subject this summer and it is expected will be prepared in the fall to offer a definite program.

The great need of the Institution is for a larger endowment to enable it to extend the scope of its activities in the "increase and diffusion of knowledge among men." During the 76 years of its existence, except for several generous contributions for specific objects, the income of the Institution has not been materially increased. With the great increase in its scientific activities and output of publications, it becomes more and more difficult to make the limited income cover the mounting expense, and many opportunities to carry on valuable scientific investigations must be passed by every year. It is hoped that some one, recognizing the advantageous position of the Institution for promoting scientific work in America, will provide a suitable endowment.

FINANCES.

The permanent investments of the Institution consist of the following:

Deposited in the Treasury of the United States	$1,000,000

CONSOLIDATED FUND.

Miscellaneous securities carried at a cost of $177,965.28, either purchased or acquired by gift, and constituting the consolidated fund, namely:

West Shore Railroad Co. guaranteed 4 per cent first mortgage bonds, due in 2361	$42,000
Cleveland Electric Illuminating Co. first mortgage 5 per cent gold bonds, due in 1939	10,000
Atchison, Topeka & Santa Fe Railway Co. 4 per cent general mortgage bonds, due in 1995, gift	2,000
Chesapeake & Ohio Railroad Co. first consolidated mortgage 5 per cent bonds, due in 1939, gift	2,000
Baltimore & Ohio Railroad Co. 5 per cent refunding general mortgage bonds, due in 1995, gift	5,000
P. Lorillard Co. 7 per cent gold bonds, due in 1944, gift	6,000
Liggett & Myers Tobacco Co. 7 per cent gold bonds, due in 1944, gift	6,000
New York Central & Hudson River Railroad Co., 4 per cent gold debenture bonds, due in 1934	4,000
City of Youngstown, Ohio, 6 per cent municipal bonds, due in 1928	3,000
Real estate 7 per cent trust notes on improved property in the District of Columbia, due in 1925	5,000
Northern Pacific—Great Northern joint convertible 6½ per cent gold bonds, due in 1936	41,500
New York Central Railroad Co. refunding and improvement 5 per cent bonds, due in 2013	10,000

Brooklyn Rapid Transit Co.[1] 5 per cent secured gold notes due in 1918	$3,500
United States first Liberty loan	200
United States second Liberty loan	100
United States third Liberty loan	10,150
United States fourth Liberty loan	50
United States war-savings stamps, series of 1918	100
Atchison, Topeka & Santa Fe Railway Co. 5 per cent preferred stock, gift	shares 125
American Smelting & Refining Co. 7 per cent preferred stock, gift	do 60
Baltimore & Ohio Railroad Co. 4 per cent preferred stock, gift	do 125
California Electric Generating Co. 6 per cent preferred stock, gift	do 100
Electric Bond & Share Co. 6 per cent preferred stock, gift	do 20

The sums invested for each specific fund or securities acquired by gift are described as follows:

Fund.	United States Treasury.	Consolidated fund.	Total.
Smithson fund	$727,640.00	$1,429.14	$729,069.14
Habel fund	500.00	.....	500.00
Hodgkins general fund	116,000.00	37,275.00	153,275.00
Hodgkins specific fund	100,000.00	.....	100,000.00
Rhees fund	590.00	199.00	789.00
Avery fund	14,000.00	20,489.80	34,489.80
Addison T. Reid fund	11,000.00	3,679.00	14,679.00
Lucy T. and George W. Poore fund	26,670.00	8,444.00	35,114.00
George K. Sanford fund	1,100.00	374.00	1,474.00
Chamberlain fund	.....	35,000.00	35,000.00
Bruce Hughes fund	.....	9,894.76	9,894.76
Lucy H. Baird fund	.....	1,260.58	1,260.58
Virginia Purdy Bacon fund	.....	46,900.00	46,900.00
Hamilton fund	2,500.00	500.00	3,000.00
Charles D. and Mary Vaux Walcott research fund	.....	11,520.00	11,520.00
Caroline Henry fund	.....	1,000.00	1,000.00
Total	1,000,000.00	177,965.28	1,177,965.28

Mr. B. H. Swales, custodian, section of birds' eggs, continues to favor the Institution with his valuable assistance in the form of contributions for the purchase of specimens for the division of birds. This year his contributions have amounted to $400.

Dr. William L. Abbott has contributed $2,000 for the purpose of continuing the collecting of natural history specimens. The Australian expedition, the expense of which was maintained entirely by Doctor Abbott for three years, has been successfully concluded, and work in new fields is contemplated in the near future.

[1] The traction problem in New York is still unsolved, and the Brooklyn Rapid Transit Co.'s finances remain in the hands of receivers.

Mr. John A. Roebling has made further gifts to the Institution to the extent of $15,771.38, to aid in the maintenance of astrophysical stations in Chile and in Arizona and for the publication of scientific papers.

The executors of the Freer estate have transferred to the Institution 6,546 shares of Parke, Davis & Co., to apply to the Freer residuary fund. The shares of this corporation now received for the several specific purposes provided by Mr. Freer are as follows:

	Shares.
Curator's fund, Freer Gallery of Art	1,742
Court and grounds fund, Freer Gallery of Art	1,742
Court and grounds, maintenance fund, Freer Gallery of Art	435
Freer residuary fund	16,546
Total	20,465

To pay inheritance and Federal taxes, it became necessary, with the approval of the Board of Regents, to place a loan with a local trust company for that purpose. The loan is being gradually reduced and now amounts to $170,000.

Dividends and interest on securities acquired from the Freer estate have amounted to $83,127.36. Thirty thousand dollars have been expended to liquidate the above-mentioned obligation, and $55,034.48 for purposes prescribed by the testator, including the purchase of art objects.

The sum of $55,823.44, constituting the balance of the building fund, was transferred to the books of the Institution, and $32,122.78 has been expended. With the addition of a credit transferred from another Freer fund, the balance available for completion and equipment of the building is $32,074.97.

The Institution's income for general expenses is received periodically and at times is in excess of immediate requirements. A part of this income is deposited on time at the rate of 3 per cent per annum. This year interest acquired principally in this manner amounted to $2,033.93.

The income during the year for current expenses, consisting of interest on permanent investments and other miscellaneous resources, was $61,872.14, receipts from Freer bequest $138,950.80. other revenues for specific purposes, $50,850.04; which, with cash on hand and subject to check on July 1, 1921, amounting to $11,229.34, constituted a total of $262,902.32.

The disbursements, described more fully in the annual report of the executive committee, were classed as follows: General objects of the Institution, $62,749.17; investments and expenditures for specific purposes, $33,553.24; temporary advances in excess of repayments, $2,578.50; cash deposited on time, $40,500; disbursed

from revenues of Freer bequest, $117,157.26; and $6,364.15 in cash and deposited subject to check.

The Institution was charged by Congress with the disbursement of the following appropriations for the year ending June 30, 1922:

International Exchanges		$50,000.00
American Ethnology		46,000.00
International Catalogue of Scientific Literature		7,500.00
Astrophysical Observatory		15,500.00
National Museum:		
Furniture and fixtures	$20,000.00	
Heating and lighting	70,000.00	
Heating and lighting (deficiency)	4,000.00	
Preservation of collections	312,620.00	
Preservation of collections (deficiency)	15.84	
Building repairs	10,000.00	
Books	2,000.00	
Books (deficiency)	3.02	
Postage	500.00	
		419,138.86
National Gallery of Art		15,000.00
National Zoological Park		125,000.00
Additional land for Zoological Park		2,500.00
Total		680,638.86

There was also appropriated for printing and binding $91,000, to cover the cost of printing and binding the Smithsonian annual report and reports and miscellaneous printing for Government branches of the Institution.

RESEARCHES AND EXPLORATIONS.

Each year the Institution sends out, as far as its limited funds permit, expeditions for the purpose of exploring scientifically little-known regions of the earth, or to conduct needed field work in more familiar localities, thus furthering one of its principal objects, the "increase of knowledge." It is also able to cooperate advantageously with other institutions by contributing members of its scientific staff to expeditions already organized and financed. The results of the more noteworthy of these expeditions are here described briefly, and the field work of the various branches of the Institution will be found in the appendixes to this report.

GEOLOGICAL EXPLORATIONS IN THE CANADIAN ROCKIES.

During the summer and early fall of 1921 your secretary carried on geological field work in the Canadian Rocky Mountains in continuation of previous years' work in this region. His objects were to secure data on the pre-Devonian strata of the Sawback Range

in Ranger Brook Canyon and to conduct a reconnaissance of the pre-Devonian formations to the Northwest as far as the headwaters of the North Fork of the Saskatchewan River, Alberta.

The field season was an unusually unfavorable one for geological work. During the three months in the field 35 days were stormy, 28 cloudy and cold, and snow fell on 20 days in August and September. As a result, not more than one-third of the work planned was accomplished before the party was driven back to the railroad by heavy snows.

On our way north we crossed over Pipestone Pass and down the Siffleur River. Clearwater River heads in glacial gravels on the east side of the Siffleur about 2 miles north of Pipestone Pass. Twenty-five miles farther to the northwest at the point where the south branch (Mistaya Creek), the middle branch (Howse River), and the north branch unite to form the Saskatchewan River there are some beautiful and instructive views of the surrounding mountains. The Mount Forbes massif on the left is a superb mountain mass and in the distant center is Division Mountain at the head of Glacier Lake Canyon which we visited in 1919, on the right Survey Peak and beyond two unnamed points. The Glacier Lake section of the pre-Devonian and Upper Cambrian formations was studied on the northern slopes of the Mount Forbes massif.

Twelve miles northeast of Mount Forbes the cliffs of Mount Murchison rise high above the dark forested slopes and present a view of the Devonian and pre-Devonian formations that is unequaled in all this region of peaks, cliffs, and broad canyon valleys.

Opposite Mount Murchison on the north side of the Saskatchewan, Mount Wilson presents another section of the pre-Devonian formations, the upper end of which is a massive white quartzite formed of the sands of the beaches over which the Devonian Sea deposited a thick layer of calcareous sediments abounding in the remains of corals and various invertebrates of the time. On the west, Mount Wilson rises directly above the North Fork of the Saskatchewan, which here flows through a narrow picturesque inner canyon.

PALEONTOLOGICAL FIELD WORK IN THE UNITED STATES.

Dr. R. S. Bassler, curator of the division of paleontology in the National Museum, was occupied during the field season in collecting geologic material and in mapping and studying the economic resources of the Franklin quadrangle in Williamson County, Tenn., in cooperation with the Geological Survey of that State. This region is of considerable economic interest on account of the phosphate and oil shale possibilities. The numerous outcrops of Ordovician and later Paleozoic formations contain a great number of fossils,

and Doctor Bassler was able to make a considerable collection of these needed for the Museum study series. He also secured several large exhibition specimens illustrating various geological phenomena, among these being a large mass of limestone composed entirely of the dismembered calices and columns of a large species of crinoid or sea lily in which the individual fragments are perfectly preserved and admirably illustrate the formation of a limestone through the accumulation of this type of animal remains.

An interesting stratigraphic observation was made on the efficacy of the coral reefs of the Ordovician in rock formation. A massive limestone bed about 15 feet thick, representing a middle Ordovician formation, here contains but a single coral reef, but within 10 miles the number of intercalated coral reefs has so increased that the formation attains a thickness of over 250 feet.

In April Mr. C. W. Gilmore, associate curator of vertebrate paleontology, was authorized to undertake a trip into New Mexico "for the purpose of making collections of geological material for the National Museum and determining the advisability of preserving certain lands in northern New Mexico for national monumental purposes." Mr. Gilmore was obliged to report that—

> Since the many square miles of "bad lands" surrounding the reserved area are equally fossiliferous and in places present much more favorable territory for the recovery of fossil remains than any observed within the boundaries of the monument, and also since the greater part of these surrounding areas lie within Pueblo grants, over which Federal control has been relinquished, there would be no advantage in retaining governmental control of so small a part of the area as is represented in the proposed monument.

Mr. Gilmore did, however, find a contiguous fossiliferous area in the Santa Clara Pueblo grant and secured for the Museum a well-preserved skull and other bones of a small rhinoceros, and, in an adjoining Pojoaque Pueblo area, remains of an extinct camel. The most promising area for collecting would appear to lie within land grants over which the Government has at present no control.

In January, this same year, Mr. J. W. Gidley, assistant curator of this division, was authorized, in cooperation with the United States Geological Survey, to conduct field explorations in the San Pedro and Sulphur Springs Valleys of southern Arizona, and on the completion of this work to visit the La Brea asphalt deposits of southern California, and from there go to Agate, in Nebraska, for the purpose of securing other exhibition material. The work in Arizona was eminently successful, Mr. Gidley shipping some 24 boxes having an aggregate weight of 5,000 pounds. The bulk of this collection, he reports, represents "a practically new Pliocene fauna containing about 60 vertebrate species, most of which are mammalian."

BOTANICAL EXPEDITION TO THE ORIENT.

As noted in last year's report, Dr. A. S. Hitchcock, custodian of the section of grasses of the National Museum, visited the Orient under the auspices of the Department of Agriculture for the purpose of collecting and studying grasses, especially the bamboos. As the specimens collected come to the National Museum, it will not be out of place to here mention briefly Doctor Hitchcock's work. The trip occupied about eight months, ending in December, 1921, and the regions visited included the Philippines, Japan, China, and Indo-China.

Japan is not very favorable for the collecting of grasses, as it is mostly a forested region and there is comparatively little open country. The bamboos were of interest, as there are many species. In the Lake Hakone region the hills were covered for miles with a single species of bamboo (*Arundinaria chino*), 4 to 8 feet high, often to the exclusion of everything else.

China, on the other hand, was very rich in grasses. One of the surprises of the trip was to find so much open grass land in a country that is said to be very thickly populated. The cities of China are very much crowded and the valley lands are intensively cultivated, but the hills are unoccupied and almost unused. This is in striking contrast to our own western regions where, except in national forests and other protected areas, the grass lands are extensively grazed. The basic reason for this condition in China appears to be the risk from bandits. The valley lands can be protected but the hills are open to the attack of robbers.

The expendition was very successful, and a large and valuable collection of grasses was brought back. The technical results of the work will be published later by the Department of Agriculture or the National Herbarium of the National Museum.

AUSTRALIAN EXPEDITION.

Through the generosity of Dr. W. L. Abbott, Mr. Charles M. Hoy continued his work of collecting for the Museum specimens of the very interesting fauna of Australia. The work was terminated during the winter and Mr. Hoy returned to the United States in May, 1922. The results of this expedition are of especial value for two reasons: First, the Australian fauna has heretofore been but scantily represented in the Museum, and, second, the remarkable fauna of that continent is rapidly being exterminated through various causes. The specimens received during the year bring the total up to 1,179 mammals, including series of skeletal and embryological material; 928 birds, with 41 additional examples in alcohol; and smaller collections of reptiles, amphibians, insects, marine specimens, etc.

For assistance and courtesies extended to Mr. Hoy while in Australia the Smithsonian Institution wishes to make grateful acknowledgment to the authorities of the Australian Museum, Sydney; the Queensland Museum, Brisbane; the South Australian Museum, Adelaide; the West Australian Museum and Art Gallery, Perth; and the Tasmanian Museum and Art Gallery, Hobart; also and particularly to Dr. Charles Hedley and Dr. Charles Anderson, of Sydney; Harry Burrell, Esq., of Kensington, New South Wales; and Capt. S. W. White of Fulham, South Australia.

BIOLOGICAL EXPLORATION IN THE DOMINICAN REPUBLIC.

Dr. W. L. Abbott, whose generosity in years past has enabled the Institution to take advantage of many opportunities in biological and other explorations, himself visited during the year the Dominican Republic, working in both the Samana Peninsula and the region lying between Sanchez (at the head of Samana Bay) and Puerto Plata, on the north coast. Having visited this region before, he was able to select new and interesting localities for collecting.

Doctor Abbott's work included botanical, zoological, and ethnological collecting, and the specimens sent in to the National Museum will go far toward completing the various series representing this region. Some 4,000 plants were collected, of which about 20 per cent were ferns. The ethnological material, including aboriginal Indian pottery and idols, is of great interest and has been described and figured in the annual pamphlet on the explorations and field work of the Institution.

ENTOMOLOGICAL EXPEDITION TO ALASKA.

Dr. J. M. Aldrich, associate curator of insects in the National Museum, spent several weeks during the field season collecting insects in Alaska. The Government railroad from the southern coast to Fairbanks, now nearing completion, offered an opportunity for travel not heretofore existing, and it was felt that it was important to know more about the insect fauna of this great region in view of the fact that the population will undoubtedly increase with the completion of the railroad. Regarding his work, Doctor Aldrich says:

> The expedition resulted in the accession of about 10,000 specimens of Alaska insects, nearly all from the interior region. As far as they have been studied up to the present time they indicate three somewhat distinct faunal regions in the territory covered.
>
> First, the maritime fauna consisting of the insects living upon the seashore and depending upon the ocean for necessary conditions of existence. Insects of this group extend down the coast, in many cases as far as the

State of Washington and some even so far as San Francisco, while it is presumed that they would also be found more or less in the Asiatic side of Bering Sea.

The second element is that of the humid mountain region along the coast; a considerable part of this fauna extends to Puget Sound, Mount Rainier, and in less degree to other mountains of the Pacific Northwest. The relation of this element to the Asiatic fauna is very little known.

The third element of the Alaska fauna, as far as observed, is that of the dry interior and especially of the Yukon Valley, which has many elements in common with northern Minnesota, Wisconsin, and Michigan, Ontario, the Adirondack Mountains of New York, and the White Mountains of New Hampshire. Many of the insects of this group also occur in the Rocky Mountains of Colorado and no doubt further exploration will show that they occur in other mountains of the western United States. Those which represent a more northern range also reappear in Labrador collections and presumably extend across North America, although we have no collections from intermediate points. This element contains many species known from Finland and the Scandinavian Peninsula in Europe, presumably extending in their distribution across Russia and Siberia.

In most orders of insects Alaska has a comparatively large fauna. There are very numerous species of the two-winged flies, or Diptera; and from Doctor Aldrich's long experience with this group he naturally paid special attention to collecting in this order.

Bumblebees and wasps are conspicuous insects everywhere on flowers; and in the absence of darkness bumblebees were observed to work as late as 10:30 at night in Fairbanks. Grasshoppers were strikingly scarce, only two species being found and in all but half a dozen specimens. Mosquitoes in the interior are exceedingly abundant, as is well known. Especial attention was given to them in collecting, and two species previously undescribed were among the material brought back. It appears, however, that the most troublesome species are the same ones which occur in somewhat less numbers in the Pacific Northwest in occasional favorable localities. Horseflies are very numerous in the region at Fairbanks, where they are commonly called mooseflies, since the moose is more common than the horse.

The exploration of Alaska, especially the interior, from an entomological point of view, is important in itself and also forms a link in the study of a much broader problem—that of the entire Holarctic fauna which extends almost continuously around the globe in the vicinity of the Arctic Circle. It is a matter of great scientific interest to determine how much of this northern fauna is the same in the New World as in the Old, and also to determine how much of the fauna farther south, as, for instance, in the United States, has been derived from this northern region. It is hoped that opportunity will arise to carry this exploration much farther, not only in Alaska, where as yet only a beginning has been made, but also in other northern regions, as, for instance, Labrador, Greenland, and Siberia.

THE INSTITUTE FOR RESEARCH IN TROPICAL AMERICA.

The recently organized Institute for Research in Tropical America, of which the Smithsonian Institution is a member, is hoping to establish a research station in Panama. Such a station when properly equipped will serve as a center for the prosecution of research upon problems in tropical biology and agriculture, and as a center from which biological explorations can be made.

FLORA OF THE PHILIPPINE ISLANDS.

At the request of Gen. Leonard Wood, Governor General of the Philippine Islands, a plan for the preparation of a flora of the Philippine Islands was drawn up by the Institution, together with an estimate of the cost. This work, which it is proposed will be accomplished through cooperation of the Smithsonian Institution with the Philippine Government, will be of the greatest importance to the agricultural interests, and, since the prosperity of the Philippines is primarily dependent on agriculture, to the islands themselves. In addition to these material benefits, such a flora would be of great value to science, and a large number of specimens of rare and valuable plants from the Philippines would come to the National Herbarium as a result of its preparation.

At the close of the fiscal year funds had not been appropriated for beginning the work.

BAIRD MEMORIAL COMMITTEE.

To celebrate the centenary of the birth of Spencer Fullerton Baird, second secretary of the Smithsonian Institution, February 3, 1923, there was formed early in 1922 the Baird Memorial Committee. It was decided at a preliminary meeting that a public meeting should be held in Washington on February 3, 1923, at which addresses would be delivered and announcements made of the form of memorial or memorials that had been decided upon, and that wreaths should be placed on the grave of Baird in Oak Hill Cemetery, the bust of Baird in the American Museum of Natural History in New York City, the Baird memorial bowlder of the American Fisheries Society at Woods Hole, and the Baird memorial tablet at the Bureau of Fisheries in Washington.

The form which the memorial to Professor Baird should take was not definitely decided upon, several plans having been considered. Among these were a bust or tablet to be erected in the Smithsonian grounds, the establishment of a Baird memorial medal to be awarded for specially meritorious work in science, the publication of a memorial volume of original scientific papers by Baird's associates or followers, and a fisheries exhibit, preferably a museum.

DEVELOPMENT OF MULTIPLE-CHARGE ROCKET.

The development of a model multiple-charge rocket, mentioned in previous reports, for the purpose of demonstrating the principle, is being continued by Prof. Robert H. Goddard, of Clark University, under a grant from the Hodgkins fund.

The specific work of the past year has been the development and test of certain new features which will increase considerably the

effectiveness of the apparatus. A discussion of these, in detail, is deferred for a later report. Additional financial support has been granted for the work by Clark University.

PUBLICATIONS.

A total of 164 volumes and pamphlets were issued during the year by the Institution and its branches. Of these publications, there were distributed a total of 165,196 copies, including 251 volumes and separates of the Smithsonian Contributions to Knowledge, 20,777 volumes and separates of the Smithsonian Miscellaneous Collections, 27,263 volumes and separates of the Smithsonian annual reports, 97,806 volumes and separates of the publications of the National Museum, 14,215 publications of the Bureau of American Ethnology, 3,159 special publications, 706 volumes of the Annals of the Astrophysical Observatory, 64 reports on the Harriman Alaska expedition, and 812 reports of the American Historical Association.

The Institution carries out one of its chief functions, the "diffusion of knowledge," by means of its various series of publications. They embrace the results of investigations and systematic studies in nearly every branch of natural science, and are distributed, in most cases free of charge, to important libraries, educational institutions, and scientific establishments throughout the world. In order to assist in creating a greater popular interest in scientific matters, the annual report of the Institution has always contained a general appendix consisting of a large selection of authentic, semipopular articles reviewing recent advances in every branch of scientific activity. There is a widespread and growing demand for this publication, showing an increased appreciation of the value of science and scientific investigations.

Besides the annual report, the Institution issues two series of publications, the Contributions to Knowledge and the Miscellaneous Collections. The publications of the National Museum and the Bureau of American Ethnology are mentioned in the reports of those branches appended hereto.

Of the series of Smithsonian Miscellaneous Collections, 9 papers were issued during the year, among them one paper by your secretary in the series on Cambrian Geology and Paleontology, and the usual annual pamphlet describing and illustrating the various scientific expeditions sent out or cooperated in by the Smithsonian Institution.

Allotments for printing.—The congressional allotments for the printing of the Smithsonian reports and the various publications of the branches of the Institution were practically used up at the

close of the year. The allotments for the coming year ending June 30, 1923, are as follows:

For printing and binding the Annual Reports of the Board of Regents, with general appendixes, the editions of which shall not exceed 10,000 copies	$10,000
Under the Smithsonian Institution: For the annual reports of the National Museum, with general appendixes, and for printing labels and blanks, and for the bulletins and proceedings of the National Museum, the editions of which shall not exceed 4,000 copies, and binding, in half morocco or material not more expensive, scientific books and pamphlets presented to or acquired by the National Museum Library	37,500
For the annual reports and bulletins of the Bureau of American Ethnology, and for miscellaneous printing and binding for the bureau	21,000
For the annual report of the National Gallery of Art and for printing catalogues, labels, and blanks	1,000
For miscellaneous printing and binding:	
The International Exchanges	200
The International Catalogue of Scientific Literature	100
The National Zoological Park	300
The Astrophysical Observatory	300
For the annual report of the American Historical Association	7,000
	77,400

Provided, That the expenditure of this sum shall not be restricted to a pro rata amount in any period of the fiscal year.

Committee on printing and publication.—The purpose of the Smithsonian advisory committee on printing and publication is to make recommendations regarding the merit and suitability of all manuscripts submitted for publication by the Smithsonian Institution or its branches and also to consider all other matters relating to printing and binding under the Institution. During the past year eight meetings were held and 100 manuscripts acted upon. The membership of the committee is as follows: Dr. Leonhard Stejneger, head curator of biology, National Museum, chairman; Dr. George P. Merrill, head curator of geology, National Museum; Dr. J. Walter Fewkes, chief, Bureau of American Ethnology; Mr. N. Hollister, superintendent, National Zoological Park; and Mr. W. P. True, editor of the Smithsonian Institution, secretary.

LIBRARY.

The facilities of the library have been taxed to the utmost. The number of loans for the fiscal year amounted to 14,436, and as many more books and periodicals were consulted without being taken from the buildings. Interlibrary loans to accredited libraries, where distance permits, are being continued, and in a number of instances arrangements have been made for the photostating of pages from rare volumes not permitted to leave the library.

Each day typewritten lists of original articles appearing in scientific periodicals received for the Smithsonian deposit in the Library of Congress are prepared and circulated among the heads of scientific bureaus under the Institution. These daily bibliographical lists, begun last November at the request of Secretary Walcott, have been well received from the start. Requests have come in for copies from other Government bureaus and research organizations, which it has not been possible to comply with, owing to lack of necessary equipment for the preparation of additional copies. The library now possesses more than a million volumes, pamphlets, manuscripts, and charts, there being 888,128 publications deposited in the Library of Congress, 156,275 belonging to the National Museum, and 35,000 belonging to other branches of the Institution. The number of additions for the fiscal year was 15,796.

As noteworthy additions to the various branch libraries might be mentioned that of the Göttingische Gelehrte Anzeigen for 1758, 1760, 1808, 1813, and 1814 to the Smithsonian deposit, by gift of the Gesellschaft für Wissenschaften zu Göttingen; Serindia, by Sir Aurel Stein, to the office library, at present deposited in the Freer Building, the gift of the Secretary of State for India; and the second and third volumes of Beebe's Monograph of the Pheasants, added to the library of the National Zoological Park.

NATIONAL MUSEUM.

The year has been an unusually busy one for the Museum, but although of late years its activities have greatly increased and its scope widely extended, the appropriation for its maintenance has remained practically the same for the past 11 years. Much credit is due the members of the Museum's staff for the fine results recorded from year to year. Undoubtedly the most important event of the year was the receipt and installation of the Herbert Ward collection of African ethnologica and sculptures. This collection, one of the most important ethnological units in the world, was brought together by Herbert Ward, an Englishman, who was with Stanley on his famous exploring expedition through Africa. It consists of 2,700 ethnological specimens and 19 superb sculptures in bronze of African natives by Mr. Ward.

An actual beginning was made during the year toward establishing the Loeb collection of chemical types, noted in the 1920 report. Two specially constructed cabinets were received from the Chemists' Club of New York, and a portion of each of seven new chemical compounds discovered in the Department of Agriculture were deposited in the collection. It is planned to solicit all available new chemical material, with the view of eventually making of the Loeb collection a complete series for the use of investigators in chemistry.

The Museum acquired during the year a total of 359,677 specimens. These are described somewhat in detail in the report on the Museum, appended hereto, but it will be of interest to mention here a few of the more important accessions. In anthropology the most important addition was the Herbert Ward African collection mentioned above. A large collection of the brilliant ancient pottery from the ruins of Casas Grandes, Chihuahua, Mexico, was received through the Archeological Society of Washington, and a remarkable series of aboriginal pottery collected by Dr. J. Walter Fewkes in the neighboring Mimbres Valley, N. Mex., was also placed on exhibition. A number of pianos were added by Mr. Hugo Worch to his notable collection, among them a magnificent gilt harpsichord made by Pleyel, Paris.

In the department of biology the outstanding feature of the year's accessions is the collection of about 100,000 insects collected by Dr. William Mann in South America, especially eastern Bolivia. Another important collection of insects was that made by Dr. J. M. Aldrich in Alaska, which numbered around 10,000 specimens. A considerable consignment of biological material, mostly vertebrates, was received from Mr. Hoy, who has been working in Australia under the auspices of Dr. W. L. Abbott. This material brings the important Australian expedition to a most successful termination.

In geology a number of valuable additions were made to the collections, among them specimens of Bolivian tin and tungsten ores from Mr. F. L. Hess; rich examples of carnotite and hewettite presented by the Standard Chemical Co., Naturita, Colo.; eight gold nuggets donated by Mr. Frank Springer; a large mass of meteoric iron from Owen Valley, Calif., the gift of Mr. Lincoln Ellsworth, of New York; a number of beautiful and valuable gems purchased for the Isaac Lea collection through its endowment fund; and a considerable amount of paleontological material, both vertebrate and invertebrate.

The divisions of mineral and mechanical technology have devoted their time largely to a more perfect and permanent arrangement of the great amount of exhibition material already on hand, while the divisions of history, textiles, and graphic arts report many valuable and interesting additions to their collections.

In addition to the explorations and field work mentioned earlier in this report, the Museum sent out or cooperated in various other expeditions. Mr. Arthur de C. Sowerby continued his work in China under the auspices of Mr. Robert Sterling Clark, who generously contributed all the material collected to the Museum. A shipment of vertebrates and other biological material was received from this expedition during the year. Mr. Paul C. Standley,

through the cooperation of various agencies, spent five months in botanical collecting in El Salvador and Guatemala, bringing back over 6,000 specimens. Another botanical expedition, consisting of Dr. F. W. Pennell and Mr. E. P. Killip, was in western Colombia at the close of the year under the auspices of various scientific organizations. The purpose of the exploration was to study the flora and secure botanical specimens in this region, as one of a series leading up to a complete study of the flora of northern South America.

The auditorium and adjacent rooms of the Museum were used by numerous societies and organizations for meetings, congresses, and lectures. The Museum published during the year 9 volumes and 78 separate papers. These are described somewhat in detail in the "Report on publications," Appendix 10 of this report. The number of visitors to the National History Building during the year was 441,604; to the Arts and Industries Building, 262,151; and to the Aircraft Building, 46,380.

NATIONAL GALLERY OF ART.

Although the number of art works accessioned by the National Gallery during the year falls short of the average of recent years, nevertheless progress in the gallery's activities has been satisfactory. The greatest handicap to its work continues to be lack of exhibition space. It is believed that the falling off in number of accessions noted above is in part due to this shortage of space, as owners of valuable art works very naturally desire to see them adequately housed and exhibited. The urgent need of a suitable gallery for the national collections, already valued in the millions, will be readily understood when it is considered that until the past year the accessions to the collections were estimated at hundreds of thousands annually. If accessions are turned elsewhere on account of the lack of space to exhibit them, it is evident that in a few years the loss will amount to more than the cost of a building.

Among the accessions received during the year was a portrait of President Grant, by Thomas Le Clear, presented by Mrs. U. S. Grant, jr.; an oil painting entitled "The Signing of the Treaty of Ghent," by Sir A. Forestier, presented to the Smithsonian Institution by the Sulgrave Institution; a painting entitled "Tohickon," by Daniel Garber, provided through the Henry Ward Ranger bequest; and a portrait of Edwin H. Harriman, an artist's proof etching, one of 21 from the copper. A number of interesting art works were loaned to the gallery during the year, among them being 71 portraits in pastel, in a series of 22 life-size groups of Union and Confederate veterans of the Civil War, painted from life by Walter Beck, of Brooklyn, N. Y., 50 years after the Battle of Appomattox.

loaned by the artist through Mr. Walter M. Grant, of New York City.

Preliminary steps had been taken at the end of the year toward the acceptance of a rich collection of British masterpieces brought together by the late John H. McFadden, of Philadelphia. The collection comprises 44 notable examples of the work of nineteen British artists, and the acceptance of this valuable loan is regarded with much favor.

A number of paintings were acquired from the income of the Henry Ward Ranger bequest and assigned to various art institutions throughout the country. The terms of this bequest stipulate that any of the art works so acquired may be claimed during a certain period after the artist's death by the National Gallery of Art, remaining thereafter the property of the National Gallery. The selection and distribution of these purchases is entrusted to the National Academy of Design.

The income from the Bruce Hughes bequest is to be used to establish and maintain a section of the library of the National Gallery for reference works of art, to be known as the Hughes alcove. During the year the first purchases were made from this fund. An illustrated catalogue of the art works of the gallery was prepared and submitted to the printer during the year, but on June 30, 1922, had not been published. A lecture on the National Gallery, illustrated by 75 slides mostly in color, was prepared, and is to be placed at the disposal of persons throughout the country who desire to present it.

The first annual meeting of the National Gallery of Art Commission was held on December 6, 1921. Reports of the committees were presented and many important matters relating to the gallery were discussed, among them the urgent need of a National Gallery Building and the problem of the acceptance of proffered works of art.

FREER GALLERY OF ART.

Work during the year on the collections of the Freer Gallery of Art included chiefly the classification and cataloguing of Chinese, Japanese, and Tibetan paintings, Chinese tapestries, and Chinese and Japanese pottery; the preliminary classification of Korean pottery and Chinese and Japanese stone sculptures and jades; and the cataloguing of American paintings, drawings, and prints.

Progress has been made also on completing certain portions of the interior of the building and on the installation of the collections. Miss Grace Dunham Guest was appointed assistant curator on January 1, 1922, and Mr. Carl W. Bishop associate curator, April 9, 1922. Miss Guest sailed for Europe on June 24, 1922, to represent the Freer Gallery at the double centennial meeting of the Société Asia-

tique de Paris, and to study European collections of oriental art, especially ceramics.

BUREAU OF AMERICAN ETHNOLOGY.

The material culture and ceremonials of the American Indian are being modified so rapidly through contact with the white race that it is imperative for the bureau to make every effort to record all possible data bearing on the aboriginal Indian culture. The desirability of preserving this material so that accurate knowledge of this interesting and vanishing race may be available for future generations is evident. Another important line of endeavor is the excavating and repairing of prehistoric Indian dwellings. These ancient ruins are the object of great popular as well as scientific interest, and it is the aim of the chief of the bureau to continue this archeological phase of the work in so far as funds will permit.

A new line of investigation has opened up for the bureau during the year, namely, the study of the material culture, and especially the architecture of the houses, of the aborigines of Alaska. The early villages of the Alaskan Indians have in many cases been deserted in the exodus to the canning factories, and the totem poles and villages which are rapidly being destroyed by the elements should be preserved in the immediate future so that they will not be lost forever. During the spring of 1922, Dr. T. T. Waterman conducted for the bureau an extended reconnaissance of the situation, bringing back many interesting data and photographs. It is intended to continue the work next year with a larger appropriation.

The work in the field and in the office of the individual members of the staff is reviewed somewhat in detail in Appendix 4 of this report, so that it will be necessary here only to give an idea of the scope of the work. The chief continued his successful archeological field work on the Mesa Verde National Park, Colo., bringing to light a most interesting and instructive ruin which he has named "Pipe Shrine House" on account of the numerous tobacco pipes found on a shrine in the kiva of this ruin. He also excavated and repaired Far View Tower, a round structure 10 feet high, which was probably used for observations of the position of the sun on the horizon at sunrise and sunset, in order to determine the time for planting and other dates important for an agricultural people.

The chief also visited the three groups of towers in Utah which he has recommended for the Hovenweep National Monument, and determined the exact situation of these ruins as a preliminary to a presidential proclamation setting aside this area as a national monument.

Dr. John R. Swanton continued work on his dictionaries of the Hitchiti and Alabama languages. Mr. J. N. B. Hewitt devoted his time to a number of Chippewa and Ottawa texts, and in continuing the preparation of the second part of his work on Iroquoian Cosmology, the first part of which has already been published by the bureau. Mr. Francis La Flesche completed and turned in during the year the manuscript of the second volume of his publication on The Osage Tribe. Dr. Truman Michelson carried on field work among the Fox Indians of Iowa, paying special attention to the linguistic relations of this and neighboring tribes. Mr. J. P. Harrington completed his bulletin on the Kiowa language and conducted field work among the Indians of the Chumashan area of California, laying special emphasis on the place names, material culture, and language.

Under the head of special researches, the chief of the bureau describes the work of Miss Frances Densmore on Indian music. During the year she recorded songs among the Yuma, Cocopa, and Yaqui tribes, making a total of nine tribes among whom this work has been done. Mr. W. E. Myer investigated Indian sites in South Dakota and western Missouri known to have been occupied by the Omahas and Osages in early historic times after they had come in contact with the whites but before they had been changed thereby to any considerable extent.

Several other interesting special researches are reviewed in the appendix on the bureau, among them field work by Mr. D. I. Bushnell, Jr., on the Cahokia mounds in Illinois; by Mr. B. S. Guha, among the Utes and the Navaho at Towoac, Colo., and Shiprock, N. Mex.; and by Mr. John L. Baer on pictographic rocks in the Susquehanna River.

INTERNATIONAL EXCHANGES.

During the year the number of packages of scientific and governmental publications sent abroad and received from foreign countries totaled 592,600 pounds. Although these figures show a decrease from the previous year, on account of the fact that shipments to Germany were resumed during that year and most of the material accumulated during the war was sent out, nevertheless there is an increase of 41,490 packages over the number sent out in 1914, the last year before the World War, showing that there is a steady growth in the work of the International Exchange service.

Exchange relations were reopened during the year with Rumania and Yugoslavia, the agencies in these countries being, respectively, the Institutul Meteorological Central at Bukharest, and the Académie Royale Serbe des Sciences et des Arts, Belgrade.

Relations were established also with the newly formed Governments of Esthonia, Far Eastern Republic, Latvia, Lithuania, and Ukrainia. Conditions in Russia and Turkey are not yet sufficiently settled to warrant the exchange of publications previously carried on between the United States and these countries.

The number of boxes shipped abroad during the year was larger than ever before, due largely to the opening of exchange relations with Yugoslovia and certain of the independent Russian States, the material for these countries having accumulated here for several years.

The regular schedule of shipments to foreign countries was resumed during the year. To Great Britain and Germany, shipments are made weekly; to France and Italy, semimonthly; and to other countries, monthly.

NATIONAL ZOOLOGICAL PARK.

The past year has been one of the most successful since the establishment of the park. The number of visitors exceeded 2,000,000; the collection of animals is larger and more important than ever before; a number of minor improvements have been completed and progress made on certain larger projects; and the reservation itself has been maintained in excellent condition. That the popularity of the park as a source of recreation and instruction continues unabated is shown by the fact that for the third consecutive year the attendance has exceeded 2,000,000, and its increasing value as a supplement to school-room instruction in natural history is demonstrated by the 205 schools and classes visiting the park during the year, with a total of 13,585 individuals.

The total number of animals on exhibition at the close of the year was 1,681, representing 482 species of mammals, birds, and reptiles. This is not only a larger number of individual animals than ever shown before, but also a larger number of different species. Among the 656 accessions received during the year, 217 were gifts. Among these may be mentioned two important collections from South America, one made by Dr. William M. Mann on the Mulford Biological Explorations of the Amazon Basin and presented by the H. K. Mulford Co. of Philadelphia, the other made by Mr. W. J. La Varre, jr., and presented by him. These two collections contain several species of South American monkeys and birds never before shown at the park. One hundred and fifty mammals, birds, and reptiles were born in the park during the year.

Under the heading of improvements the report of the superintendent mentions a large project of grading, leveling, and filling in

the west central part of the park, which was practically completed during the year. This work makes available for the exhibition of hoofed animals a large area of comparatively level ground. Also it will be possible to greatly improve the main automobile road through the park. Extensive repairs were completed on the antelope house and the older bear dens. Three large outdoor cages were built for certain birds, and many minor repairs were completed during the year. The most urgent need of the park is now a suitable restaurant building to accommodate the greatly increased crowds of visitors. The present small building is in bad condition and is entirely inadequate to meet the needs of the public. A suitable building could be erected, using lumber in the possession of the park and employing the regular park force, for about $20,000. Another urgent need is for a new bird house, the old building, erected many years ago as a temporary relief, being in a very bad state of repair. Moreover, there is not sufficient space for the very valuable and interesting collection of birds and there is far too little room for visitors in the public aisles.

ASTROPHYSICAL OBSERVATORY.

The outstanding feature of the year's work was the publication of Volume IV of the Annals of the Astrophysical Observatory, a quarto volume of 390 pages, which covers in detail the work of the years 1912 to 1920. New instruments and methods of observing are described and a mass of solar observations is presented and discussed. Many kinds of evidence are given to show the solar variability, and reference is made to applications of the results which have been made by several meteorologists.

The observing station erected on Mount Harqua Hala, Ariz., through the generosity of Mr. John A. Roebling, has been much improved, owing to the zeal of Mr. A. F. Moore, in charge of the station. Solar constant observations were made on upward of 70 per cent of the days of the year. Comparisons made during and after a visit by the director show no change in the scale of pyrheliometry, so that the results from this station are comparable with those at Montezuma, Chile. Earlier in the year the director visited the station at Montezuma, where he revised all the adjustments of apparatus and some of the methods employed there.

In June the director and Mr. L. B. Aldrich proceeded to the Smithsonian station on Mount Wilson, Calif., where a beginning was made toward installing new "solar constant" apparatus to replace that removed to the new Arizona station in 1920. By anticipation it may be said that later results were secured on the distribution of energy in the spectra of 11 of the brighter stars by bolometric work in connection with the hundred-inch telescope, and

also that the solar-energy curve was traced bolometrically with both glass and rock-salt prisms. The solar cooking apparatus on Mount Wilson referred to in previous reports suffered the loss of the cover of the oil reservoir through a high wind, and snow having gotten in, much water had leaked into the oil reservoir. It proved impossible to remedy this condition soon enough to undertake the proposed new experiments before the expedition returned to Washington in September.

In order to get the opinions of competent critics as to the value of the Smithsonian solar radiation measurements, the director wrote to the American representatives of the International Astronomical Union as follows:

> It is the intention of the Smithsonian Institution to continue daily observations at Mount Harqua Hala and Montezuma certainly until July, 1923, at which time it is proposed to consider the state of the work and the results reached with a view to deciding whether it is worth while to continue daily observations of the variability of the sun indefinitely or whether the usefulness of that work is unequal to the trouble and expense involved.
>
> An expression of opinion on the part of those interested in the subject would be of great value to the Smithsonian Institution in making this decision.

At a meeting in Washington the American representatives unanimously indorsed the work of the observatory, and later at Rome the international representatives passed a resolution expressing the same opinion. In view of these impartial indorsements of the work, it is a pleasure to announce that Mr. John A. Roebling has made it possible to assure the continuation of the solar constant stations at Harqua Hala and Montezuma until July, 1925. By that time it will doubtless be evident from the data obtained whether they should be continued longer.

A movement is under way in Australia to establish a solar observing station there similar to the Smithsonian stations. The Meteorological Service of Argentina is also proposing to equip its station at La Quiaca for solar observations, and it is expected that during the next fiscal year two sets of solar constant apparatus will be prepared for the Australian and Argentine stations.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

In the statement last year regarding the International Catalogue of Scientific Literature reference was made to the very apparent need of cooperation between organizations publishing abstracts to scientific literature and the International Catalogue. This year in the annual report of the United States regional bureau suggestions are made for an even greater consolidation of bibliographical inter-

ests. Although the combination of interests suggested would make a very large organization, there is nothing new or radical in the proposed move; it is simply an attempt to harmonize numerous plans and suggestions, all of which aim to supply aids to investigators and students in the at present difficult task of finding the published records of what has been done in the various fields of research.

The need of prompt and reliable aid is keenly apparent, and while in some subjects satisfactory aids are available in others they do not exist.

It now appears that the organization of the International Catalogue of Scientific Literature may be kept in working condition, although it is not yet possible to resume publication on account of financial conditions. Pending the resumption of publication it is felt that through the large number of regional agencies much constructive work may be done by using their influence and efforts in bringing about cooperation among similar organizations dealing with any of the subjects embraced within the scope of the International Catalogue.

NECROLOGY.

JOHN A. ELSTON.

John A. Elston, Representative in the Congress from California and Regent of the Smithsonian Institution since January 9, 1920, died in December, 1921. Although a member of the Board of Regents for such a brief period, Mr. Elston took a real and active interest in the affairs of the Institution.

JOSEPH B. LEAVY.

Joseph B. Leavy, philatelist in the National Museum since 1913, died July 25, 1921, after a lingering illness. Mr. Leavy was educated at Columbia University, and later entered into business, in which he continued for several years. He served in the Army during the Spanish War.

To him is due the credit for the excellent installation of the large collection of stamps in the Museum, which includes specimens of all new issues sent to the Post Office Department from various foreign Governments.

JAMES MOONEY.

James Mooney, ethnologist in the Bureau of American Ethnology, died on December 22, 1921. Mr. Mooney was born in Indiana in 1861, and became associated with the bureau in 1885, shortly after its organization by Major Powell. He remained a member of the staff from that time until his death.

Mr. Mooney was very widely read regarding the history of the aborigines north of Mexico, being equaled by few perhaps in this particular field. His information was most extensive, however, regarding the Indians of the southeastern woodlands and the Great Plains, and he was the leading authority on one tribe in each area, the Cherokee and the Kiowa. Several of Mr. Mooney's investigations published by the bureau are standard works in their special field.

He was one of the founders of the American Anthropological Association, a member and ex-president of the Anthropological Society of Washington, and a member of the Mississippi Valley Historical Association. Mr. Mooney's death brings to a premature close a notable scientific career.

THOMAS F. HANEY.

Thomas F. Haney, preparator in the National Museum for over 28 years, died October 8, 1921. During his service for the Museum, Mr. Haney constructed many difficult large-size models illustrating the occurrence, mining, and manufacture of various mineral resources. His skill and minutely detailed work in this field of educational exhibits will be greatly missed.

ANDREW L. FANT.

Andrew L. Fant, watchman, a faithful and efficient employee in the National Museum since 1893 and lieutenant of the watch force since 1903, died on October 6, 1921.

Respectfully submitted.

CHARLES D. WALCOTT, *Secretary.*

APPENDIX 1.

REPORT ON THE UNITED STATES NATIONAL MUSEUM.

SIR: I have the honor to submit the following report on the operations of the United States National Museum for the fiscal year ending June 30, 1922.

The year, a busy one, was marked by the multiplicity of activities, and advancement is shown in a number of directions. As set forth in the last report, the Museum is receiving practically the same appropriation that it did 11 years ago, in spite of increased scope, additional collections, and advanced cost of all material and labor necessary to its maintenance. That the Museum attains the fine results recorded from year to year is owing, in large measure, to the personal qualities of the members of its staff, to whom much credit is due.

The organization and staff of the Museum have undergone no noteworthy changes; policy and plans have remained opportunistic in the absence of funds to enable them to be considered in advance.

Of prime importance this year was the receipt and installation of the Herbert Ward collection of sculptures of African natives and of African ethnological specimens. Like the bequest of James Smithson to the United States, this gift from a British subject to the American people is unique and deserves mention also as a wonderful representation of the native dignity of an aborginal race, typical of all aborigines. Its installation is noteworthy as marking an advance in the display of such objects.

A beginning was made under the terms of the will of Dr. Morris Loeb for the establishment of the Loeb collection of chemical types in the National Museum. This collection forms a separate entity in the department of arts and industries. An advisory committee cooperates in its management, consisting of Dr. C. L. Alsberg, chairman; Dr. Victor Lenher, Mr. James K. Senior, Dr. G. C. Spencer, representing the Bureau of Chemistry of the Department of Agriculture; and Mr. F. L. Lewton, representing the Museum and in charge of the collection.

The two specially constructed storage cabinets were received from the Chemists' Club of New York City, and a portion of the original material of each of seven new chemical compounds, discovered and prepared in the Department of Agriculture, were transferred to the

Loeb collection. The members of the committee have offered to solicit additional original chemical material for the series. Arrangements were made with trade journals for advance notice of the publication of new chemical compounds, in order to facilitate prompt solicitation.

Steps were taken to have greater use made of the facilities afforded Washington by the National Museum. Through arrangements with the authorities of the public schools of the District of Columbia the Museum, when notified in advance, furnishes expert guidance by a member of its staff to scholars and teachers visiting its halls. In some instances such visits have resulted in further work along similar lines after the return to their school buildings and on several occasions have been followed by talks to the students in their classrooms by members of the staff of the Museum. Through cooperation with the Wild Flower Preservation Society of America, the Audubon Society of the District of Columbia, and the American Forestry Association, the Museum arranged a series of six Saturday morning lectures in the auditorium of the Museum for honor pupils of the seventh and eighth grades of the public schools, and the American Forestry Association awarded blue ribbons for the best bird houses submitted by the pupils.

The schools of Washington, in common with the higher educational establishments of the country, have long shared the benefits of the duplicate specimens distributed by the Museum for educational purposes, and this year was no exception.

The value of the Museum to the commercial interests of the National Capital, as well as to its educational interests, was demonstrated by a series of lectures by the curator of textiles given to several groups of employees handling textiles in one of the large department stores of the city, who, at the solicitation of their firm, came to the Museum during business hours for the purpose.

The influence of the Museum in education is being felt outside its immediate vicinity, through the large delegations of students visiting it annually, often as part of their courses of instruction, and also through its assistance in the preparation of textbooks. Photographs and essential data of the exhibits pertaining to the mineral industries were supplied to the Pennsylvania State Board of Education, and to other inquirers.

President Harding, on October 24, 1921, under authority of the legislative, executive, and judicial appropriation bill for the fiscal year ending June 30, 1913, directed the Bureau of Efficiency to prescribe a uniform system of employee ratings for all departments, and requested the heads of the departments to put the system into effect. Ratings were first to be established for employees engaged

in clerical or routine work, such as clerks, stenographers, bookkeepers, messengers, and skilled laborers, and afterwards to be extended to employees engaged in professional, scientific, technical, administrative, or executive work, or any other work involving for the most part original or constructive effort. This was inaugurated by a survey of all the positions existing in the Museum on November 15, 1921, carefully prepared and submitted to the Bureau of Efficiency. An initial report on the efficiency of each employee was made dating May 15, 1922, and similar reports are to be made every six months hereafter. The installation of this system added considerably to the duties of the officials of the Museum.

The changing of the system of keeping Government accounts, to make the items of expenditure identical in all Government offices, whether large or small, likewise, temporarily at least, added to the work this year in the administrative office. Efforts were also made toward unifying other business methods of the Government offices generally, as to the handling of supplies, traffic matters, etc.

BUILDINGS AND EQUIPMENT.

The National Museum completely occupies two large and two small buildings, besides considerable space in two other structures. The combined floor space is approximately 670,000 square feet. To keep these buildings in repair requires all the available appropriation, so that radical changes in arrangements, however much needed, are almost impossible. This year by the removal of one partition and the erection of another, two small exhibition halls were added to the floor space for the display of specimens in the Arts and Industries Building, though the storage space was correspondingly diminished. Other repairs consisted, as usual, of repainting of walls and ceilings in places where most needed, the replacing of certain worn-out floors, and repairs to roofs, gutters, etc. The hot-water heating system was extended to the concrete building in the east court of the Natural History Building, replacing the temporary heating arrangements installed there when the structure was erected during the World War.

In the Natural History Building a thorough investigation was made of the dome and the great piers supporting it. The slight displacement of the stone arches which span the piers, the opening of joints at the end of the balustrades under these arches and in the fourth-story floor at the ends of the piers, have been brought about by a movement at the upper end of the piers, doubtless caused by the eccentric application of the weight of the dome. The piers are fully braced by a large number of steel beams to the walls of the building and, since the walls are successfully resisting the pressure

from the piers, the movement of the latter, it is believed, will probably not proceed much farther. Careful observations and measurements will, however, be made at intervals of a few months to determine if any further displacement occurs.

By the acquisition of 37 exhibition cases and 116 pieces of storage, laboratory, and office furniture, there were on hand at the close of the year 3,679 exhibition cases and 11,572 pieces of storage, laboratory, office, and other furniture, besides 83,500 drawers, trays, boxes, and wing frames.

COLLECTIONS.

The total number of specimens acquired by the Museum during the year was approximately 359,676. Additional material to the extent of 995 lots, chiefly geological, was received for special examination and report. Nearly 20,000 specimens were lent to specialists for study, mainly on behalf of the Museum, and about 33,000 specimens were sent out in exchange, for which the Museum received valuable material. Over 10,000 duplicate specimens were used as gifts to educational establishments. Of these nearly half were contained in regular sets of labeled material previously prepared for shipment, and the remainder comprised specially selected lots to meet particular cases. The duplicates were chiefly fossil invertebrates, minerals, and ores, material illustrating rock weathering and soil formation, miscellaneous geological material, mollusks, and marine invertebrates, with smaller lots of specimens from the collections of insects, mammals, fishes, birds, archeology, ethnology, textiles, physical anthropology, and wood technology.

Anthropology.—Collections in unusual number and of scientific value were received by the department of anthropology. Especially worthy of praise is the Herbert Ward African collection, heretofore mentioned, given to the Museum by Mrs. Herbert Ward. This collection, forming one of the most important ethnological units in the world, was begun by Herbert Ward in Africa during the first great period of exploitation by Livingstone and Stanley. It consists of 2,700 specimens of African ethnologica and is illustrated by 19 superb sculptures in bronze by Mr. Ward. The whole collection is displayed to advantage in the halls of ethnology in the Natural History Building.

Through the friendly offices of the Archæological Society of Washington, the division of American archeology received a large collection of the brilliant ancient pottery from the ruins of Casas Grandes, Chihuahua, Mexico. The remarkable aboriginal ceramics collected by Dr. J. Walter Fewkes in the neighboring region, the Mimbres Valley, N. Mex., were placed on public view. From the

National Geographic Society's expedition in Chaco Canyon, N. Mex., conducted by Mr. Neil M. Judd, considerable material was forwarded.

An ornate gilt bronze statue of Buddha from the Imperial Palace at Peking, containing rolls of inscribed prayers, was received by the division of Old World archeology from Maj. Murray Warner through Mrs. Gertrude Bass Warner, of Eugene, Oreg.

Mr. Hugo Worch has added a number of pianos to his collection, and especially noteworthy is a magnificent gilt harpischord made by Pleyel, Paris, France. The collection of violins bequeathed to the Museum under the terms of the will of Dwight J. Partello was lost to the Museum, as it was found that through a previous bill of sale the collection belonged to one of his daughters.

In art textiles mention should be made of a collection of specimens of lace of high class, a permanent deposit by Miss Emily G. Storrow. In ceramics a selection of American art pottery was supplied for the exhibit of the National Gallery of Art.

A special exhibit of tiles made in the United States and assembled by the Associated Tile Manufacturers to illustrate the result of 44 years' development of an American industry was shown from May 16 to June 20, 1922, in two rooms off the foyer in the Natural History Building.

Biology.—From the numerical standpoint the collections of the department of biology show less uniform and healthy growth than during the fiscal year 1921. The actual number of specimens received, 318,950, represents, it is true, an increase over the previous year, but this increase is only 67,437, while the year 1921 showed an increase of no less than 114,720 over its predecessor.

Together with the decrease in relative increment has gone a general decrease in the scientific importance of the new accessions. Three curators regard this importance as increased over that of the previous year's accessions, but only one of these (insects) feels called upon to express enthusiasm. Of the six others five report essentially stationary conditions and one (fishes) a falling off.

The great outstanding feature among this year's accessions is the collection of about 100,000 insects of all orders, made by Dr. William M. Mann in South America, chiefly in eastern Bolivia. In Alaska another unusually important collection of insects was obtained by Dr. John M. Aldrich. The final consignment of Mr. Hoy's Australian material (mostly vertebrates) presented by Dr. William L. Abbott, brings the important and successful Australian expedition to a close.

The National Herbarium through cooperation with the Department of Agriculture acquired the very large private herbarium of Dr. Otto Buchtien of over 45,000 specimens, rich in material from

Bolivia, Chile, and Paraguay, the Bolivian flora being particularly well represented.

Many other smaller collections were received, including mammals from Alberta and plants from British Columbia collected by Secretary and Mrs. Walcott.

The work of remedying defects in the biological exhibition has been practically confined to the mammal halls. Good progress has been made in routine curatorial and preparatorial work in the various collections, but everywhere this work is suffering from the insufficiency of space and of personnel.

Geology.—A satisfactory increase in the geological collections is noted, although the accessions number slightly less than last year, 217, with an aggregate of 23,504 specimens being recorded.

Valuable additions were made to the collections of Bolivian tin and tungsten ores by Mr. F. L. Hess; rich examples of carnotite and hewettite, the best thus far found in the United States, were acquired through the generosity of the Standard Chemical Co., Naturita, Colo.; and large uranophane-bearing sandstone specimens were presented by Mr. John J. Bonner, Lusk, Wyo. Gold nuggets, eight in number, the largest weighing 4½ ounces, from the Maxwell Land Grant, N. Mex., were donated by Dr. Frank Springer, and Hon. Holm O. Bursum presented examples of torbernite, a radium-bearing mineral from White Signal, N. Mex. Other gifts to the economic collections include examples of diamond-bearing rock from Pike County, Ark., and slabs of building stones supplied by various dealers.

The most notable addition to the meteorite collection is the magnificent mass of iron from Owens Valley, Calif., gift of Mr. Lincoln Ellsworth, New York City. Examples of other falls and finds, 10 in number, either new to the collection or hitherto poorly represented, were acquired chiefly through exchanges.

The mineral collections were benefited through gifts which include at least three exhibition specimens. Large fine crystals of colemanite, donated by Mr. W. S. Russell, Los Angeles, an attractive specimen of cuprite showing deep red crystals on native copper, by Dr. R. O. Hall, San Jose, Calif., and a zoned rhodenite of unusual form, by Col. Washington A. Roebling, Trenton, N. J., are notable among these. Valuable foreign minerals were acquired through exchange; type materials were transferred by the United States Geological Survey; a series showing the effect of radium rays on the color of minerals, beryl crystals from Brazil, and examples of nesquehonite, demantoid garnet, and other forms from Italy were acquired by purchase; and interesting collections were made in the field by the assistant curator. Gems of beauty and value have been added to the Isaac Lea collection through its endowment fund,

including a series of uncut diamonds from the mines of the Arkansas Diamond Corporation, Murfreesboro, Ark.; a unique cut gem of orthoclase from Madagascar; a blue zircon from Australia; and a series of fresh-water pearls from the rivers of the Mississippi Valley. A number of individual gifts are also recorded.

Paleontological material was received from Mexico, Central and South America, India, and several European localities, these being chiefly Mesozoic and Cenozoic, while numerous collections from Paleozoic rocks of the United States and Canada were made by the curator or presented by interested friends. Unusually well preserved cetacean remains obtained in the Miocene deposits along Chesapeake Bay; valuable reptilian material acquired by exchanges; skulls and bones of extinct buffaloes, presented by the John A. Savage Co., Crosby, Minn.; and remains of the Beresovka mammoth, are among the notable accessions of vertebrate material.

Mineral and mechanical technology.—In the division of mineral technology attention was confined entirely to a more permanent and complete arrangement of the exhibits already on hand, and new material consisted chiefly of photographic transparencies which were installed in the respective exhibits to which they referred. Apart from this work, the division was chiefly engaged in cooperative educational work with the Pennsylvania State Board of Education through Mr. Samuel S. Wyer, of Columbus, Ohio. The plans of the State Educational Board call for revision of the seventh-grade geography course to include the study of the State's mineral resources. The extent of the division's cooperation may be judged from the fact that it has supplied a considerable amount of the data for text and illustrations from the models of the many mineral industries exhibited in the Museum.

The division of mechanical technology was extremely busy, primarily, in regrouping its collections and rearranging objects in the collections so as to tell a story rather than merely represent a period in development, in an endeavor to impress the student with the significance of the material rather than its mere existence; and, secondarily, through the receipt of over 100 per cent more objects than were received the preceding year. In the line of special investigations, those inaugurated last year, particularly with regard to the developments in aeronautical engineering, were continued.

Textiles, wood technology, foods, and medicine.—The collections under the supervision of the curator of textiles, which, besides textiles, embrace wood technology, food, medicine, and miscellaneous organic products, were increased by many gifts and by transfer and loan of property from other Government bureaus amounting to nearly 3,000 objects. The most important of these are as follows:

From the Department of Commerce, several hundred specimens of industrial raw materials not heretofore represented in the collections, which had been sent to the department by American consular offices and trade commissioners for the purpose of encouraging foreign commerce. There were added by gift beautiful specimens of silks, fur fabrics, and drapery textiles contributed by American manufacturers to show the progress of textile industries in this country.

To the collections arranged to show the importance of wood and the industries based upon the use of that raw material, there were added two series of specimens illustrating the manufacture and use of sulphite wood pulp for writing papers, one showing in detail the steps in the process, and the other the exact quantities of each ingredient entering into 100 pounds of finished paper; also exhibits showing the importance and uses of American walnut, many examples of articles turned from wood, and specimens of laminated wood wheels for motor vehicles.

The collections in the division of medicine were enlarged by extensive series of specimens showing the manufacture of surgical dressings, pills, plasters, surgical ligatures, and clinical thermometers; specimens of essential oils and related aromatic substances; important alkaloids and alkaloidal salts used in medicine; and a series of charts showing the treatment of rabies, typhoid fever, and whooping cough.

Graphic arts.—The specimens acquired in the division, while less than half in number, are still fully as important, artistically and technically, as the 1920–21 specimens. The most important individual gift was that of the sixteenth century methods of making type, in which all the specimens were made by or prepared by Mr. Dard Hunter, Chillicothe, Ohio. Mr. Hunter himself made the punches, struck the matrices, and cast the type. This is one of a series consisting of printer's ink, paper, and type making, which, with the promised modern methods of type making, will be about complete. Several gifts combined have greatly improved both the technical and historical series of collotype. The Campbell Art Co., of Elizabeth, N. J., gave a valuable and instructive technical exhibit of color printing, and beautiful examples of the process were also furnished by Foster Bros., of Boston, the Medici Society of America (Inc.), and by Rudolf Lesch, of New York City. These are examples of the finest collotype work being produced to-day, and make an excellent showing of this process of photomechanical reproduction. A new process for reprinting books has been developed by the Polygraphic Co., of Berne, Switzerland, who donated a complete exhibit. In this so-called Manul process the negative is ob-

tained upon a sheet of very thin paper without the use of a camera or lens.

The series of pictorial photographs collected this year, over 100 in number, is a very important collection of artistic photography representing 17 of the foremost pictorial photographers of the world. The successful collection of this material was largely due to efforts and suggestions of Mr. Floyd Vail, of the New York Camera Club. The gift by Maj. Murray Warner through Mrs. Gertrude Bass Warner of 42 autochromes, the work of Major Warner, deserves mention, as they preserve the wonderful color schemes of the Panama-Pacific Exposition, as well as being fine specimens. A loan from Mr. Earle W. Huckel, of Philadelphia, of several printed books contains one dated 1497, Theology, by Lockmayer, which is the earliest book in the division; also a beautiful book from the famous Moretus Press dated 1696. The most beautiful example of presswork and typography shown is a copy of The Well at the World's End, printed by William Morris at the Kelmscott Press in 1896.

Many small and individual objects have augmented various series, adding to their extent and beauty, as, for example, two beautiful water colors by Mr. W. H. Holmes, Director of the National Gallery of Art, and a black and white original, loaned by Franklin Booth.

One hundred photographs of snow crystals, by Mr. W. A. Bentley, form a valuable addition to the technical collections. A notable loan exhibit of artistic photography, the work of Mr. Floyd Vail, was shown for two months and attracted much attention.

History.—During the past fiscal year, the historical collections have received a number of additions of more than usual interest and importance. These include the following: The American flag, which, after receiving military honors in the Sorbonne in the presence of President Poincaré, was flown with a French flag at the summit of the Eiffel Tower and saluted with 101 guns, April 22, 1917, in celebration of the entry of the United States into the World War on the side of the Allies. This flag was presented by the French ambassador, M. Jusserand, to President Harding at the White House on Decoration Day, May 30, 1922, and deposited in the Museum by the President. A series of very handsome silk American flags, presented to Gen. John J. Pershing in recognition of his services as commander-in-chief of the American Expeditionary Forces in France during the World War and loaned to the Museum by him. Two sectional relief maps of northern France, one made of papier-mâché and one of plaster, presented by Marshal Haig and Marshal Petain, respectively, to the Hon. Medill

McCormick, and by him presented to the Museum. The first of these consists of eight sections, 22 by 27 inches in size, showing when united the territory bordering the British battle front from Dunkirk to Amiens. The second consists of 111 sections, each 19 by 25 inches, and shows the region of the French front from Vermand to Courgenay, in great detail. Another relief map of much importance is one received from the United States Marine Corps, showing the region about Belleau Wood. The numismatic collections relative to the World War have been increased by a number of examples of the medals and decorations issued in the United States and European countries during the war.

The original historical collections have been increased by a sword carried during the War of the Revolution by General Washington, a cane bequeathed to him by Benjamin Franklin, and a sword owned by Gen. Andrew Jackson. These three objects were transferred to the Museum from the Department of State by joint resolution of Congress approved February 28, 1922. From the same department by transfer was received the small writing desk used by Thomas Jefferson when he drafted the Declaration of Independence in Philadelphia in 1776, which bears a memorandum in his own hand attesting to its history. A single addition was made during the year to the collection of costumes worn by the mistresses of the White House. This was the dress worn by Mrs. Andrew Jackson, jr., on the occasion of a reception given at the White House in her honor in 1831, and lent to the Museum by Mrs. Rachel Jackson Lawrence, of the Hermitage Association.

Work on the collections.—The care and preservation of the collections require a large proportion of the energies and time of the scientific staff and present many difficulties to be surmounted. In ethnology, the installation of the Herbert Ward collection led to a recasting of the African collection generally. The conditions hampering the development of the biological exhibition since the later years of the World War have continued, making it impossible to do more than remedy special defects as opportunity presented. A general overhauling of the unmounted larger cetacean material has placed this series in a condition to be used for the first time in many years. Commendable progress is reported in the care of the geological collections, though comparatively few new exhibits were installed.

The assignment of the entire east gallery of the Arts and Industries Building for the use of the division of medicine necessitated a complete rearrangement of all the cases and the installation of a number of new exhibits. In the division of mechanical technology a complete inventory was made of the collections, the Museum catalogues as far back as 1876 being carefully examined and checked

with the specimens. The collections of graphic arts on display in the Smithsonian Building were rearranged so that exhibits of a kind, both historical and technical, are located near together for easy examination.

The classification of the collections by members of the staff has produced the usual amount of research work on the material intrusted to their care; and the usual generous cooperation of outsiders has been of the utmost assistance in enhancing the scientific value of the collections. The total number of papers by members of the staff, or based partly or wholly on National Museum material by outsiders, published during the year is 332.

EXPLORATIONS AND FIELD WORK.

From the standpoint of exploration and expeditions, the year just completed shows very little improvement over 1920–21. The work carried on by various other governmental agencies, particularly by the United States Geological Survey, the Bureau of Fisheries, the Biological Survey of the Department of Agriculture, and the Bureau of American Ethnology has, as usual, resulted in important material for the national collections.

The number of expeditions contributing material to the department of biology, according to the reports of curators, was 18, of which no less than 10 were both financed and directed by outside friends and correspondents, 7 were financed by others and partly or wholly directed by members of the staff of the Museum, while only 1 was entirely controlled by the Museum. In the department of geology, extensive field work was confined entirely to the division of paleontology.

Besides the field work described here, a number of other expeditions in which the Museum was interested are mentioned in the first part of this report under the heading "Explorations and researches."

The work of Mr. Arthur de C. Sowerby in China, interrupted by the World War, was resumed, a shipment of specimens from the Province of Fukien being received. The expenses of this work are met by Mr. Robert Sterling Clark, who generously contributes all the material to the Museum. Special effort is being directed to securing vertebrates from southern and other parts of China not hitherto represented in the national collections.

Dr. William M. Mann, while attached to the Mulford Biological Exploration of the Amazon Basin, collected a large number of insects and some miscellaneous material of other kinds. This expedition was organized by the H. K. Mulford Co., of Philadelphia, under the direction of Dr. H. H. Rusby, chiefly for the purpose of studying drug plants, but also for making general biological collections. By invitation, Doctor Mann was attached as entomologist and assistant

director and during the last 3 of the 10 months of the expedition was in charge, on account of the illness of Doctor Rusby.

Dr. Paul Bartsch continued his experiments in heredity on land mollusks of the genus Cerion, under the joint auspices of the Smithsonian Institution and the Carnegie Institution, of Washington. He has been working upon a survey of the distribution of the native species in the Florida Keys. By the use of a seaplane, detailed for the purpose by the Navy Department, Doctor Bartsch was able in four days to fly at low altitude over the entire region and note on charts all the visible grass plots—the habitat of the Cerions. It will now be possible by means of the charts to examine the native colonies without loss of time in locating them. Mr. John B. Henderson, Regent of the Smithsonian Institution, made a rather hurried trip to Jamaica to personally collect living specimens of the Helicid genus Thysanophora for anatomical study toward a proposed monograph of the group. This little expedition proved unusually successful and of great benefit to the work in hand, as well as to the mollusk collections.

Mr. Paul C. Standley carried on botanical exploration in Central America, through cooperation with the Gray Herbarium, the New York Botanical Garden, the Bureau of Plant Industry of the Department of Agriculture, and Mr. Oakes Ames, the latter being interested in the orchids of this region. About five months were spent in El Salvador, and nearly a month in Guatemala. The collections, over 6,000 botanical specimens, will be divided among the contributing institutions.

Another botanical expedition was in the field at the close of the year. Dr. F. W. Pennell, of the Philadelphia Academy of Natural Sciences, accompanied by Mrs. Pennell, and Mr. E. P. Killip, of the Museum, is conducting a six months' exploration of western Colombia, on behalf of the Gray Herbarium, the New York Botanical Garden, the Philadelphia Academy of Natural Sciences, and the Museum. Mr. Oakes Ames is contributing also to the expense of the expedition. This is one of a series toward a complete study of the flora of northern South America.

The biological expedition alluded to as the only one under the exclusive control of the Museum was a trip to the interior of Alaska undertaken by Dr. John M. Aldrich, associate curator of insects. The Alaska Engineering Commission of the Department of the Interior furnished Doctor Aldrich with horses and their subsistence and with transportation on the Alaskan Railroad. About 10,000 specimens were collected, consisting mainly of Diptera and Hymenoptera, with a fair number of Hemiptera.

The expedition of the Museum of the American Indian (Heye Foundation) to New Mexico under Mr. F. W. Hodge furnished

valuable skeletal material, as has been the case for several years past. The exploration of Pueblo Bonito in the Chaco Canyon, N. Mex., by the National Geographic Society under the direction of Mr. Neil M. Judd during the summer of 1921 was largely preliminary. The exploration will be continued through a number of seasons and the collections are to become the property of the National Museum.

Early in the year Mr. F. W. Foshag collected minerals from interesting cave deposits in the Grand Canyon, near Supai, Ariz., a project made possible through the courtesy of Mr. C. A. Heberlein, operating in the region. Mr. Foshag also made field trips to southern California and Nevada in connection with research work at the University of California, the results of which were likewise added to the national collections.

Doctor Bassler spent his vacation in July, 1921, in geological fieldwork in the central basin of Tennessee, under the auspices of the Geological Survey of that State. The field offered such opportunities that arrangements were made for another summer's work in the same general area. During the greater part of June, 1922, therefore Doctor Bassler, in company with Dr. E. O. Ulrich and Mr. R. D. Messler, of the United States Geological Survey, was occupied in making stratigraphic sections and collecting fossils over the entire central basin, an area of about 8,000 square miles. The ultimate object of this work is the preparation of a monograph on the stratigraphy and paleontology of Tennessee. On the completion of his work in Tennessee, in 1921, Doctor Bassler proceeded to Springfield, Ill., where casts of type specimens in the State museum collections were made, in accordance with the department's plan to complete so far as possible the representation of type specimens in the national collections. Through the courtesy of Mr. E. J. Armstrong, of Erie, Pa., Doctor Bassler visited all the classical Silurian and Devonian localities in northwestern Pennsylvania and western New York during the latter part of September to obtain field knowledge of the detailed geology and to collect carefully selected sets of fossils illustrating the numerous formations of the region. The work was highly successful, and the large collections of Devonian fossils in the Museum concerning which exact stratigraphic data have been lacking can now be determined and arranged in necessary detail.

Dr. E. O. Ulrich, of the United States Geological Survey, spent the summer of 1921 in continuation of his field researches on the early Paleozoic rocks of eastern North America, and previous to joining Doctor Bassler in Tennessee, as noted above, studied the Silurian stratigraphy of Pennsylvania and Maryland. Mr. N. H. Boss made several short trips collecting in the Miocene deposits

along the Chesapeake Bay, all of which were under the auspices of the National Museum. These trips were unusually productive in the recovery of well-preserved cetacean remains.

Dr. George P. Merrill did a little work on his own initiative while in Maine on a vacation, and Mr. Shannon on a two-day trip to Port Deposit and Conowingo, Md., and Peach Bottom, Pa., visited a number of commercial granite, feldspar, talc, and slate mines and quarries.

MEETINGS, CONGRESSES, AND RECEPTIONS.

The Museum is seldom able to arrange regular lecture courses, but it does diffuse much knowledge through the lectures and proceedings of the various governmental, scientific, and educational agencies using its meeting facilities. The auditorium and adjacent council rooms afforded accommodations during the year for about 150 meetings, covering a wide range of subjects.

The governmental agencies availing themselves of these opportunities included the State Department, the War Department, the Treasury Department, the Department of Agriculture, the Department of Labor, the Interdepartmental Social Hygiene Board, and the Federal Power Commission. The scientific and technical groups included the National Academy of Sciences, the National Research Council, the American Relief Administration, the International Association for Identification, the American Surgical Association, the American Federation of Arts, the Wild Flower Preservation Society of America, the National Association of Postmasters of the United States, the National Association of Office Managers, the Liberty Calendar Association of America, the George Washington Memorial Association, the Committee on the Baird Memorial, the Organizing Committee of the Nineteenth International Congress of Americanists, the Anthropological Society of Washington, the Archæological Society of Washington, the Audubon Society of the District of Columbia, the Biological Society of Washington, the Chemical Society of Washington, the Entomological Society of Washington, the Federal Photographic Society, the Organization of Appointment Clerks, the Philosophical Society of Washington, the Shakespeare Society of Washington, and the Washington Academy of Sciences. The educational and miscellaneous agencies included the American University; the School of Foreign Service and the School of Medicine of the Georgetown University; the Federation of Citizens Associations; the General Federation of Women's Clubs; the Potomac Garden Club; the George Washington Post No. 1, American Legion; the Matrons and Patrons Association of 1922, Order Eastern Star; the Smithsonian branch of the Federal Employees Union No. 2; the

Smithsonian Auxiliary of the District of Columbia Chapter of the American Red Cross; and the Smithsonian Relief Association.

The Museum was the scene of several receptions, the first being probably the largest, the most elaborate, and the most successful affair of its kind ever held in the Museum. This was the reception on November 23, 1921, by the city of Washington, through the Commissioners of the District of Columbia and a committee of citizens, to the delegates to the International Conference for the Limitation of Armament, when some 5,000 persons representing the official, social, and business life of Washington showed respect to the delegates to that conference.

On the evening of February 18, 1922, an informal reception and private view of the collection of Chihuahua pottery, loaned to the Museum by the Archæological Society of Washington was held in the public exhibition halls on the first floor. This was preceded by a lecture in the hall below by Dr. Hamilton Bell, on the Sculpture of Japan, under the auspices of the Archæological Society.

Another reception, on April 24, formed part of the program of the annual meeting of the National Academy of Sciences. This was in honor of Dr. and Mrs. H. A. Lorentz, of Leiden, and followed a lecture in the auditorium by Doctor Lorentz on Problems of Modern Physics.

A function which brought to the Museum representatives of the diplomatic corps and others was the formal presentation to the American Nation, on March 1, of the Herbert Ward collection of sculptures and African ethnology. In the northeast corner, first story, of the Natural History Building, surrounded by the works of her gifted husband and his unrivaled collection illustrating the handicrafts of the native African, the presentation was made by Mrs. Ward, and the donation accepted by Vice President Coolidge as chancellor of the Institution.

MISCELLANEOUS.

The publications issued by the Museum comprised 9 volumes and 78 separate papers. The Museum distribution of volumes and separates to libraries and individuals aggregated 97,806 copies. This, however, by no means indicates the number of its publications put in circulation during the year, for one of the separates of the Proceedings, on the Mosquitoes of the United States, issued in June, proved so popular that the War and Navy Departments arranged through the Superintendent of Documents for liberal distributions of the paper, and the Bureau of Public Health reprinted it.

The library received 2,023 volumes and 4,185 pamphlets, mainly through gifts and exchanges, bringing the Museum collection up to

60,681 books and 95,594 pamphlets. Typewritten lists of original articles appearing in scientific periodicals reaching the Institution for the Smithsonian deposit at the Library of Congress have been circulated among the head curators of the Museum for their information and dissemination among the staff generally. There is a demand from other Government departments and research organizations for copies of these lists which the Museum is unable to supply, through lack of mechanical equipment and assistants.

The number of visitors to the Natural History Building was 441,604; to the Arts and Industries Building, 262,151; to the Smithsonian Building, 83,384; and to the Aircraft Building, 46,380. All the Museum exhibition halls are open free to the public every weekday in the year. In addition those in the Natural History Building are open every Sunday afternoon, and this year those in the Smithsonian Building were open on Sunday afternoons in April. All the Museum offices and exhibition halls were closed, however, on November 11, 1921, on account of the burial of America's unknown soldier.

Respectfully submitted.

W. DE C. RAVENEL,
Administrative Assistant to the Secretary, in charge
United States National Museum.

Dr. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 2.

REPORT ON THE NATIONAL GALLERY OF ART.

SIR: I have the honor to submit the following report on the affairs of the National Gallery of Art for the year ending June 30, 1922.

The second year of the existence of the National Gallery as a separate administrative unit of the Smithsonian Institution closed with substantial reasons for satisfaction with the progress made, notwithstanding the fact that the accessions of art works fall short of the average for a number of previous years. The activities of the gallery continued in all essential respects in directions identical with those of the preceding year, the personnel being limited to a director and a secretary with clerical assistance, a guard, three watchmen, two laborers, and two charwomen.

Full information regarding the inception and growth of the gallery within the Institution and as a subsection of the department of anthropology of the National Museum may be found in the report of the secretary of the Institution for the preceding year, and more especially in an earlier publication (Bulletin 70, U. S. National Museum) prepared by former assistant secretary, Dr. Richard Rathbun.

Although art was recognized as a legitimate field of activity in the organization of the Institution, and on equal terms with science, and although numerous paintings and other works were acquired as the years passed, no special provision was made for their accommodation, space being assigned them in various places as the years passed, and no special provision was made for adding to the collection by purchase. Since the completion of the Natural History Building the collections have found space in that building, finally occupying the large central hall which was subdivided by screen partitions for their accommodation. This resource has, however, reached its limit, and additions accepted can find exhibition space only by storing the less important works previously acquired. This condition is most unfortunate since the inflow of gifts and bequests, upon which the gallery depends for accessions, is governed largely by the character of the accommodations afforded. The vital importance of this shortage of space will be appreciated when it is stated that the in-

crease of art works by means of gifts and bequests to the Institution for the 10 years since appropriate exhibition space became available in the new Natural History Building, ending June 30, 1921, and aside from the rich accessions of the Freer gift, has averaged in estimated money value upward of $500,000 per year. The year just closed has fallen far short of that valuation, not exceeding $10,000, a result due in part, at least, to a knowledge of the real conditions on the part of such owners of collections as have reached the stage where the future of their accumulations has become a matter of great concern.

The urgent need of a gallery building is thus strongly emphasized, for it is apparent that should 10 years elapse before a building for this purpose is erected, the loss due to delay will amount to several times the cost of a building. Another consideration of great importance is that the National Gallery is not limited in scope to painting and sculpture, but has confined its activities mainly to this narrow field because no space is available for assembling and displaying the full range of art products. It is thus most important that Americans should begin to realize, as have all other civilized nations, the great importance, the inestimable value, of art as an agency in the advancement to higher accomplishment in each and every branch of activity in which taste is an essential feature. We are the only civilized nation that has not risen to a realization of the real value of art and of the important functions of a National Gallery and that has not, save in the limited appropriations granted in 1921 and 1922 to the gallery fostered by the Smithsonian Institution, recognized art save as the handmaid of history or as an essential of architectural embellishment or landscape gardening. No important art work has, for art's sake pure and simple, ever been purchased with the approval of the United States Government. The Nation has received as gifts and bequests, art works amounting to more than ten millions in money value, and has expended on their acquirement and care possibly one two-hundredth part of that amount. The American people should at once arise to a realization of the fact that unless gallery space is provided for the accommodation of prospective additions, this inflow of art works must practically cease. This would be a national misfortune and a disaster to the Capital of the Nation.

ART WORKS ACQUIRED DURING THE YEAR.

GIFTS AND BEQUESTS.

Portrait of President Ulysses S. Grant (three-quarter length) by Thomas Le Clear, N. A. (1818-1882), painted in 1880 or 1881. Gift of Mrs. U. S. Grant, jr., of San Diego, Calif.

A large gravure reproduction of a portrait of Abraham Lincoln, taken from Douglas Volk's portrait of Lincoln painted from memory. Gift of Dr. Charles D. Walcott, Secretary of the Smithsonian Institution.

An oil painting entitled "The Signing of the Treaty of Ghent," by Sir A. Forestier, 1914. Presented to the Smithsonian Institution for the American people by the Sulgrave Institution of Great Britain and the United States, through Mr. Barron Collier, and accepted on behalf of the United States by Chief Justice William Howard Taft. Deposited by the Smithsonian Institution.

A painting by Daniel Garber, N. A., entitled "Tohickon," provided by the Henry Ward Ranger bequest through the council of the National Academy of Design, trustees of the fund.

Portrait of Edwin H. Harriman, being an artist's proof etching, one of 21 from the copper. Gift of Mrs. E. H. Harriman, New York City, through Dr. Charles D. Walcott.

Portrait bust (bronze) of Maj. Gen. George Owen Squier, Chief Signal Officer, United States Army, by M. W. Daikaar. Gift of General Squier.

LOANS.

Salutation (copy) by Albertinelli, and Holy Family (copy), by Andrea del Sarto, and an *erba* or painting in vegetable colors entitled St. Anthony and the Lions," by and old monastic painter of the time of Fra Angelica and Fra Bartolommeo. Lent by the Rev. F. Ward Denys, of Washington, D. C. Doctor Denys lent also a Minton shield, two bronze reliefs of sacred subjects, and a small landscape in oil, which he withdrew before the close of the year.

Mother and Children (Early Morning), by A. W. Bougereau (1825–1905), and Sheep, by F. Brissot. Lent by Mr. and Mrs. Walter Tuckerman, Edgemoor, Md.

Deer, by J. A. Oertel, signed 1856. Lent by Mr. Charles Townsend Abercrombie Miller, of New York City.

Portrait of Abraham Lincoln, painted in 1865 by M. S. Nachtrieb (1835–1913). Lent by Mr. Anton Heitmuller, of Washington, D. C.

A series of 10 architectural drawings by Rossel Edward Mitchell, showing the artist's plan for furthering the International Historical Museum. Lent by Rossel Edward Mitchell, Washington, D. C., and withdrawn at the close of the special exhibition during January, 1922.

Forty-six paintings, comprising kakemonos and framed pictures by Shunko Sugiura, of Tokyo, Japan. Lent by the artist and withdrawn at the close of the special exhibition, from January 18 to 27, 1922.

Series of 150 enlarged portraits in sepia, of Washington children, by Underwood & Underwood, of Washington, D. C. Lent by Underwood & Underwood and withdrawn at the close of the special exhibition, February 20 to March 5, 1922.

Plaster bas-relief portrait of Prof. Francis James Child, Scholar (1825–1896), of Cambridge, Mass., executed in 1891 by Miss Leila Usher. Lent by Miss Leila Usher, of Boston, Mass.

A collection of 100 etchings and water-color drawings by Francisco Gonzales Gamarra, of Lima, Peru, illustrating ancient Peruvian art, recent historical art, and current subjects. Lent by Mr. Gamarra and withdrawn at the close of the special exhibition which was open to the public during June, 1922.

Bronze bust of Enrico Caruso (1873–1921), by Joseph Anthony Atchison; presented to the city of Washington for the Washington Opera House. Lent by the sculptor on behalf of the Washington Opera House.

Two old masters, Baptism of Christ by J. B. Tiepolo and a small landscape by R. Wilson, were added to his loan collection by Mr. Ralph Cross Johnson, of Washington, D. C.

A Moment's Rest, a large painting by William E. Norton (1843–1916), a realistic rendering of a team of four horses in charge of two men and a boy resting a moment in the shadow of a boat's hull by the water's edge while one of the men lights his pipe. Lent by the artist's daughters, Miss Gertrude M. Norton and Miss Florence E. Norton, of New York City.

Twenty-two portraits in pastel, being a series of life-size groups of Union and Confederate veterans of the Civil War, painted from life by Walter Beck, of Brooklyn, N. Y., 50 years after the battle of Appomattox; lent to the Smithsonian Institution by the artist through Mr. Walter M. Grant, of New York City. Deposited by the Institution. They are as follows:

MOSBY TRIPTYCH.

1. Left panel:
   1. Seated, left, Lieut. Fountain Beatty, Alexandria, Va.
   2. Seated right, John Russel, scout, Berryville, Va.
   3. Standing, Frank H. Rahm, Richmond, Va.
2. Central painting:
   4. Left, Charles Grogan, Baltimore, Md.
   5. Center, Col. John S. Mosby.
   6. Right, Dr. W. L. Dunn, Glade Springs, Va.
3. Right panel:
   7. Seated, Lieut. A. R. Richards, Louisville, Ky.
   8. Standing, Dr. James G. Wiltshire, Baltimore, Md.

FEDERAL FORCES.

4. Fifty Years After the Battle. Fifth New York Volunteer Infantry, First Duryée Zouaves, known as "The Fighting Fifth."

Left to right—

1. Trumpeter Robert Fofar, Brooklyn, N. Y.
2. Trumpeter Robert F. Daly (once the drummer boy), New York City.
3. John F. Connell, New York City.
4. Gilbert Boyd, Brooklyn, N. Y.
5. John Hefferman, Flushing, Long Island.

5. Map of the Peninsular Campaign, Fifth New York Volunteer Infantry. First Duryée Zouaves, known as "The Fighting Fifth."

1. Left upper, John C. L. Hamilton, Elmsford, N. Y.
2. Second, Edward Whiteside, Brooklyn, N. Y.
3. Seated, left, James Collins (address not given).
4. Seated, George F. Wilson, Mount Vernon, N. Y.
5. Seated, George A. Mitchell (address not given).
6. Standing, right, Samuel H. Tucker (with rifle), Ridgefield Park, N. J.

6. Sheathing the Sword.

1. Standing at left, Peter G. Wagner, New York City.
2. Seated, Lieut. William H. Uekele, New York City.
3. Second, standing, Alfred Atkins, Rosells Park, N. Y.
4. With sword and gun, Harry Jones, Long Island City, N. Y.
5. Extreme right, George H. Myers, New York City.

7. Comrades of the Fighting Fifth.

1. Left, Daniel J. Meagher, New York City.
2. Right, Albert Shellworth, Jersey City, N. J.

8. Drummer Boy of the Fighting Fifth After Gaines Mills.

Robert F. Daly, New York City, was a drummer boy before he was 13 and had seen 17 battles. He endeared himself to his regiment, the First Duryée Zouaves, especially at Gaines Mills, where he carried water to the men fighting, from a spring more than a mile to the rear. On the 7-day retreat to the ships the men carried the boy on their shoulders. When the regiment returned to New York, the boy's father discovered him in line, snatched him from the march, and sent him back to school.

9. The Signal. After the Battle of Big Bethel. John Tregaskis, Brooklyn, N. Y., Fifth New York Volunteer Infantry, Duryée Zouaves.

After the Battle of Big Bethel the Union forces were marching by parallel roads in pursuit of the enemy. During the night at the cross-roads they fired at each other. To avoid a repetition of the error they used the white of their turbans around their arm as a signal.

10. The First Sharps Rifle. Homer D. Jennings, St. Cloud, Fla.

The Sharps rifle was used for the first time before Gaines Mills, Va. It was a repeating rifle and was used by the Fifth New York Volunteer Infantry, Duryée Zouaves. There were just enough of the rifles to arm the end men of companies, but the effect upon the opposing forces was bewildering and disastrous. General Sykes was in command.

11. Adelaide Smith. One of the first Army nurses.

She volunteered at Brooklyn, was with Grant's army through the Peninsular campaign, especially during the last years of the Civil War.

The silver cup at her left is the cup which she carried all through the war and with which she gave water to thousands of wounded men.

The One hundred and sixty-fifth New York, or Second Duryée Zouaves, Volunteer Infantry.

12. The left panel, four figures with the flags.
13. Center panel, five figures, Capt. Mathias Johnston, leader.
14. Third, or right, panel, five figures, with guns.

15. Doctor Beyea, chaplain, and noted as a singer at camp fires, Lafayette Post, New York. Painted in 1914.
16. Fisher of the Fifth New York Volunteer Infantry, Duryée Zouaves.
17. The Beecher Regiment Returning Its Flag to Plymouth Church.
    1. Seated, left, William Pink, Brooklyn, N. Y.
    2. Standing, left, Henry Metcalf, Brooklyn, N. Y.
    3. Standing, Richard Conlon, Brooklyn, N. Y.
    4. Standing, Charles Balogh, Brooklyn, N. Y.
    5. Center, Capt. Miles O. Reilly, Brooklyn, N. Y.
    6. Standing, Maj. M. K. Mille, Westfield, N. Y.
    7. Standing, George O. Fowler, Whitestone, L. I.
    8. Seated, right, Gen. Louis M. Peck, Brooklyn, N. Y.

THE OLD GUARD OF NEW YORK.

18. Capt. H. Cole Smith, Eighth Connecticut Volunteer Infantry.
    Willis White, Second Regiment New York Cavalry.
    Capt. Frank Huntoon, Vermont Cavalry.
19. Judge Blanchard, Wisconsin Volunteer Infantry.
    Col. G. K. Grismer, One hundred and ninety-second New York Volunteer Infantry.
    Maj. Charles H. Heustis, Massachusetts Volunteer Infantry.
20. Col. A. E. Dick, Twenty-second New York Volunteer Infantry.
    Admiral Charles D. Sigsbee, Fort Fisher, afterwards on the U. S. S. *Maine*, seated.
    Capt. James F. Wenman, who brought the obelisk from Egypt to Central Park, New York City.
    Brig. Gen. Albert F. Davis, Spanish War Veterans.
21. Capt. L. F. Barry, Seventy-first New York Volunteer Infantry.
    O. M. Chace, Seventh New York Volunteer Infantry.
    Maj. William R. Mitchell, Wisconsin Volunteer Infantry.
    Capt. L. A. Newcome, Massachusetts Volunteer Infantry.
22. Capt. Arthur Jacobson, Seventy-first Regiment New York National Guard, and One hundred and seventy-sixth New York Volunteer Infantry.
    T. A. O'Mara, drummer boy, Fifty-ninth New York Volunteer Infantry.

THE NATIONAL PORTRAIT COLLECTION.

As announced in last year's report, a number of influential citizens desiring to preserve some pictorial record of the World War, organized a National Portrait Committee and arranged with a number of our leading portrait painters to paint portraits of certain distinguished leaders of America and other allied nations in the war with Germany. The members of the committee as organized are: Hon.

Henry White (chairman), Herbert L. Pratt (secretary and treasurer), Mrs. W. H. Crocker, Robert W. de Forest, Abram Garfield, Mrs. E. H. Harriman, Arthur W. Meeker, J. Pierpont Morgan, Charles P. Taft, Charles D. Walcott, and Henry Frick (since deceased).

Under this arrangement 20 portraits were painted and assembled in the National Gallery during the month of May, 1921. Later these were turned over to the American Federation of Arts for purposes of public exhibition, and at the close of the year they had been shown in the following cities: Princeton, N. J.; New Haven, Conn.; Boston, Mass.; Rochester, N. Y.; Cleveland, Ohio; Williamstown, Mass.; Amherst, Mass.; Buffalo, N. Y.; Cincinnati, Ohio; Indianapolis, Ind.; Pittsburgh, Pa.; Detroit, Mich.; Youngstown, Ohio; and Memphis, Tenn.

The portrait of Herbert Clark Hoover, by Edmund C. Tarbell, has since been added to the number.

THE McFADDEN COLLECTION.

At the close of the year preliminary steps had been taken toward the acceptance by the gallery of the loan of the McFadden collection of British masterpieces, comprising 44 notable examples of the work of Richard Parkes Bonington; John Constable, R. A.; Davis Cox; John Crome; Thomas Gainsborough, R. A.; George Henry Harlow; William Hogarth; John Hoppner, R. A.; Sir Thomas Lawrence, P. R. A.; John Linnell, sr.; George Morland; Sir Henry Raeburn, R. A.; Sir Joshua Reynolds, P. R. A.; George Romney; James Stark; George Stubbs, R. A.; Sir John Watson Gordon, R. A.; J. M. W. Turner, R. A.; and Richard Wilson, R. A. These paintings were acquired by John H. McFadden, Esq., of Philadelphia, Pa., recently deceased, during his lifetime, and by his will left in trust to the city of Philadelphia and to be intrusted to its custodianship when the Municipal Museum now in course of construction is completed. Notwithstanding the fact that there is much shortage of storage space in the halls occupied by the national collections, the acceptance of this rich collection for a limited period is regarded with much favor.

DISTRIBUTIONS.

Loans have been withdrawn by owners as follows: Portrait of Arthur Spicer, and portrait of Mary Brockerbrough Spicer, his wife, by Sir Peter Lely, lent by Miss Lucy Stuart Fitzhugh, were with-

drawn by Mrs. Daisy Fitzhugh Ayers, executrix. Genevra dei Benci, attributed to Leonardo da Vinci, withdrawn by the Misses Janet R. and Mary Buttles. Christ in the Temple, by J. P. Tiepolo; The Doctor's Visit, by Jan Steen; Dedham Vale, by John Constable; and A Young Dutch Girl, by N. Drost, were withdrawn by Mr. Ralph Cross Johnson, but returned to the gallery before the close of the year with the exception of the last named. Five portraits: Col. Mark Hopkins in Continental Uniform (copy by Robert Hinckley); Dr. Mark Hopkins, Educator, by Sarony; Hon. Edward Everett, by Asher Brown Durand; Mrs. Edward Everett, by Gambardella; and Charlotte Brooks Everett, by George P. A. Healy; withdrawn by Mrs. Charlotte Everett Wise Hopkins (Mrs. Archibald Hopkins). Clearing Up, in the Berkshires, by James Henry Moser, was acquired by the Cosmos Club from Mrs. J. H. Moser, the owner, and withdrawn by the club. The Finding of Moses, attributed to the period of Paul Veronese, withdrawn by Mrs. F. S. Bloss. Sea, Sand and Solitude, by Edward Trenchard, withdrawn by the artist. Seven paintings: Portrait of Mr. Levi Woodbury, of New Hampshire; Portrait of Mrs. Levi Woodbury, of New Hampshire; Portrait of an Old Gentleman, and St. Dominic and the Christ Child, artists not given; Landscape, attributed to Berghem; Parrot and Fruit, and Flowers, attributed to Zuccarelli; from the collection lent by the Duchess de Arcos (Virginia Woodbury Lowery Brunetti), withdrawn by Mr. Woodbury Blair, attorney in fact for the duchess. Four paintings from the loan collection of the American Federation of Arts were distributed for the federation as follows: Ducks on the Bank, by Franz Grassel, sent to E. O. Summer at Brooklyn, N. Y.; Memory of the Tyrol, by J. P. Junghanns, and The Garden, by Max Clarenbach, to the Art Institute of Chicago, Chicago, Ill.; and Portrait of Mrs. Penelope Wheeler, by George Sauter, to Messrs Budworth & Sons, New York City.

Caresse Enfantine, a painting by Mary Cassatt, belonging to the Evans collection, the property of the gallery, was lent to the American Federation of Arts to be included in an exhibition of pictures of children under the auspices of the federation, to be shown in six southern cities: Louisville, Ky.; Roanoke, Va.; Savannah, Ga.; Charleston, S. C.; Richmond and Norfolk, Va. The work elicited much favorable comment, and was returned to its place in the gallery at the close of the exhibition.

THE HENRY WARD RANGER FUND.

The purchases made by the council of the National Academy of Design from the fund provided by the income from the Henry Ward

Ranger bequest, with the names of the institutions to which they have been assigned, are as follows:

Title.	Artist.	Date purchased.	Assigned.
11. Fall Round-Up.....	Carl Rungius, N. A...	Dec. 20, 1921	Corcoran Gallery of Art, Washington, D.C.
12. Repose of Evening...	Ben Foster, N. A.....	.....do.....	San Francisco Museum of Art (offered to).
13. Forest Primeval.....	Chas. S. Chapman, A. N.A.	.....do.....	Cleveland Museum of Art.
14. The Figurine.....	Wm. M. Paxton, A. N.A.	.....do.....	Wadsworth Atheneum and Morgan Memorial, Hartford, Conn.
15. Wilton Hills.....	Roy Brown, A. N. A..	.....do.....	Hackley Gallery of Fine Arts, Muskegon, Mich.
16. Gleam on Hilltops....	Gardner Symons, N. A.	Apr. 18, 1922	Montclair Art Association, Montclair, N. J.
17. White and Silver....	Dines Carlsen.....	.....do.....	Portland Society of Art, of Portland, Me.
18. Tohickon.....	Daniel Garber, N. A...	.....do.....	National Gallery of Art, Washington, D. C.
9. East Coast, Dominica, British West Indies.	Fredk. J. Waugh, N. A.	.....do.....	Museum of History, Science, and Art, Los Angeles, Calif.

THE REV. BRUCE HUGHES ALCOVE.

Two publications have been purchased from the funds received from the income of the Rev. Bruce Hughes bequest, and placed in the gallery library as a separate unit thereof. They are:

Zoffany, R. A., John: His Life and Works. 1735–1810. By Lady Victoria Manners and Dr. G. C. Williamson. London: 1920. (No. 1.)

Life and Works of Ozias Humphrey, R. A. By George C. Williamson, Litt. D. London: 1918. (No. 2.)

LIST OF PUBLICATIONS.

Holmes, W. H. Report on the National Gallery of Art for the year ending June 30, 1921. From the Report of the Secretary of the Smithsonian Institution for 1921, pp. 45–55.

The report of the director for the first year of the gallery as a separate unit under the Smithsonian Institution, the art collections having been associated previously with the department of anthropology in the United States National Museum.

Rose, George B. The Ralph Cross Johnson collection in the National Gallery at Washington. Annual Report of the Smithsonian Institution for 1920 (1922), pp. 679–690, pls. 1–24. Reprinted from Art and Archæology, Vol. X, No. 3, September, 1920. (Smithsonian Publication No. 2649).

A Catalogue of the Art Works of the Gallery embodying introductory matter and brief biographies of the painters and sculptors represented, with full-page illustrations of 25 of the works, was prepared and sent to the printer in October, 1921. At the end of the fiscal year, June 30, 1922, it has not appeared.

ILLUSTRATED LECTURE ON THE GALLERY.

As a means of promoting the development of the gallery by making its existence and collections known to the people, a lecture has been prepared by the director, the step being due largely to the urgent request of Mrs. Summers, wife of the Hon. J. W. Summers, Representative in Congress from Washington State, who has presented it a number of times in his home State. A brief introduction is followed by the presentation of 75 slides, mostly in color, representing the Smithsonian buildings and their surroundings and the more noteworthy works of painting and sculpture preserved in the gallery, with brief biographies of the artists. The lecture is to be placed at the disposal of such persons throughout the country as may desire to present it.

THE NATIONAL GALLERY OF ART COMMISSION.

The National Gallery Commission, organized in accordance with plans formulated by the Regents of the Smithsonian Institution, held its first or organizing meeting on June 25, 1921, and its first annual meeting on December 6 of that year. The proceedings of the organizing meeting are outlined in the annual report for that year, and the proceedings of the meeting of December 6 may be here briefly outlined.

The meeting was held in the Regents' Room of the Smithsonian Institution, members present being: Daniel Chester French (chairman), Herbert Adams, Edwin H. Blashfield, Joseph H. Gest, William H. Holmes (secretary ex-officio), John E. Lodge, Frank Jewett Mather, jr. (vice chairman), Gari Melchers, Charles Moore, James Parmelee, Herbert L. Pratt, Edward W. Redfield, Charles D. Walcott (ex-officio).

The report of the executive committee, which met at the Cosmos Club on the evening of the 5th of December, was submitted and reports of the 11 subcommittees were received. These committees are as follows:

1. American painting, Edward W. Redfield, chairman.
2. Modern European painting, Gari Melchers, chairman.
3. Ancient European painting, Frank Jewett Mather, jr., chairman.
4. Oriental art, John E. Lodge, chairman.
5. Sculpture, Herbert Adams, chairman.
6. Architecture, ———, chairman.
7. Mural painting, Edwin H. Blashfield, chairman.
8. Ceramics, Joseph H. Gest, chairman.
9. Textiles. ———, chairman.
10. Prints, James Parmelee, chairman.
11. Portrait gallery, Herbert L. Pratt, chairman.

The reports of the chairmen were received with interest, and numerous additions to the membership were made.

Consideration was given to the proposed exhibit of early American paintings and sculptures, to be held in the Louvre, Paris, in the near future, and the advisability of holding a special loan exhibit of American portraits in the National Gallery in Washington received attention.

The feasibility of arranging in Washington a plan for the further development of the art interests, corresponding with that existing between the Louvre and the Luxemburg Galleries, Paris, was considered and steps were taken to determine the attitude of other galleries with respect to the suggestion.

The urgent need of a National Gallery building to accommodate the collections now occupying the very limited space allowed them in the Natural History Museum, and for future accessions, was considered, and a resolution enumerating at some length the unfortunate conditions existing and appealing to Congress for the limited fund required for the preparation of plans for a building was adopted.

The very serious problems of the acceptance and rejection of proffered works of art of all classes was discussed at length, and at the close of the meeting the advisory committee on acceptance of works took necessary action with regard to such offerings for the year as awaited consideration.

Respectfully submitted.

W. H. Holmes,
Director, National Gallery of Art.

Dr. Charles D. Walcott.
Secretary, Smithsonian Institution.

APPENDIX 3.

REPORT ON THE FREER GALLERY OF ART.

SIR: I have the honor to submit the second annual report on the Freer Gallery of Art for the year ending June 30, 1922.

THE COLLECTION.

Work carried on during the year includes the classification and cataloguing of Chinese, Japanese, and Tibetan paintings, Chinese tapestries, and Chinese and Japanese pottery; the preliminary classification of Korean pottery and Chinese and Japanese stone sculptures and jades; and the cataloguing of American paintings, drawings, and prints (inclusive of both etchings and lithographs). Important progress has been made also in the indispensable preservation work on oil paintings.

BUILDING AND INSTALLATION.

Owing to a temporary lack of applicable funds, work on the building and installation was discontinued in July and was not resumed until December. The work accomplished, however, includes the continuation—and in some instances the completion—of undertakings mentioned in the first annual report: The dais in gallery 18 has been rebuilt and stained, the walls of 15 galleries and 2 corridors have been recolored, all of the storage bags and 27 of the storage boxes for Japanese screens have been completed, the Chinese and Japanese panel storage has been finished and the panels themselves placed in their permanent storage racks. The more important items of the new work undertaken are as follows: The dais in gallery 8 has been removed, terrazzo floor has been laid in the areas thus exposed, and the walls have been covered with canvas. The two large Chinese stone slabs purchased during the previous fiscal year were set in the wall of gallery 9 and repaired, practically all of the Whistler oil painting frames have been repaired and regilded, and 16 storage racks for oil paintings have been constructed. The installation of fly screens has been effected, as has also the correction of defective doors and the reenforcing of the meeting rails of the double-hung windows throughout the basement floor. Bronze light standards have been erected outside of the north and south entrances, the

offices have been carpeted and furnished, oiling of the gallery floors has been begun, electric meters have been installed, cheesecloth screens have been provided for the ventilators in all the storage rooms, and necessary drains have been set in the lower floor at various places.

PERSONNEL.

Grace Dunham Guest was appointed assistant curator on January 1, 1922.

Ruth W. Helsley resigned, her resignation taking effect March 1, 1922.

Ruth L. Walker was appointed to fill Mrs. Helsley's post as stenographer on February 15, 1922.

Carl W. Bishop was appointed associate curator on April 9, 1922.

Miss Guest was given a two months' leave, and she sailed for Europe on June 24, 1922, to act as delegate from the Freer Gallery of Art to the double centennial meeting of the Société Asiatique de Paris, and also to study collections of oriental art—especially ceramics—in England, France, and Germany.

Respectfully submitted.

J. E. Lodge,
Curator, Freer Gallery of Art.

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 4.

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY.

SIR: In response to your request I have the honor to submit the following report on the field researches, office work, and other operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1922, conducted in accordance with the act of Congress approved March 4, 1921. The act referred to contains the following item:

> American ethnology: For continuing ethnological researches among the American Indians and the natives of Hawaii, including the excavation and preservation of archeologic remains, under the direction of the Smithsonian Institution, including the necessary employees and the purchase of necessary books and periodicals, $46,000.

The Indians of the United States are undergoing cultural changes which will in a short time so modify their material culture that little will be left in that line for the ethnologist to study. It is imperative that the bureau exert itself in every way to record the material culture and cult objects before the final change occurs. The objects illustrating this culture are now mainly preserved as heirlooms in ceremonies and it is particularly desirable that these be described and their meanings interpreted before they pass out of use completely.

In 1904 the bureau inaugurated at Casa Grande a method of archeological work which has now been adopted by most of the institutions working in the southwestern part of the United States. Previous to this time archeologists rarely paid attention to the preservation of walls of ruins, but sacrificed these in their zeal to make as large collections of artifacts as possible.

The bureau method of preserving the buildings for future students has now been adopted by other institutions, and work of this nature is being carried on at Pueblo Bonito, Chaco Canyon, by the National Geographic Society; at Chettro Kettle, in the same canyon, by the School of American Research, Santa Fe, N. Mex.; at Pecos, N. Mex, by the Phillips Academy, Andover, Mass.; and at Aztec by the American Museum of Natural History of New York. This method of archeological work has created a great interest in archeological problems, as indicated by the increased number of visitors to these ruins, and

has a great practical value as an asset to the communities in which these ruins are situated. It is the intention of the chief of the bureau to keep abreast of the other institutions in this regard.

In the past year the bureau has entered upon two new lines of work which it is believed will not only increase its scientific output by intensive research but also appeal strongly to the popular interest and to the diffusion of knowledge already acquired. For many years it has not been found practical to continue work on the Hawaiian Islands, which is mentioned as one of the important items of ethnological research in the above act of Congress. A meeting of the Pan Pacific Convention in Honolulu shows an increased interest in the study of the Polynesian islanders and their relation to the question of the peopling of America from the South Seas. Mr. Gerard Fowke, a collaborator of the bureau, was commissioned to attend this convention in the interest of the Smithsonian Institution, and he was instructed to gather whatever information he could in relation to the archeology of the people, if any, that preceded the Hawaiian race of the present day. Although his results were negative, it is gratifying that the bureau took part in this convention, as it opened up several lines of work in other islands which it may later be advantageous to follow. The Sandwich Islands lie practically on the periphery of the sphere of influence of the Polynesian culture, and local investigators have the Hawaiians well in hand. There is considerable to do in mapping the distribution of temples and ancient buildings, but this work is being rapidly done by local archeologists. It is desirable, however, that the bureau take up archeological work in Samoa or some island nearer the center of distribution of the race which has occupied almost all the land in the Pacific Ocean. The imperfect facilities for transportation from one island to another and the loss of time in transit is a serious handicap in this work.

A second line of research which promises even more to the scientific investigator and the tourist is a study of the material culture, especially the architecture, of the houses of the aborigines of Alaska. In the growth of the canning industry the Indians who formerly inhabited southern Alaska have been drawn away from their aboriginal villages, leaving them deserted and their totem poles and buildings to the mercy of fire and decay. The monuments are rapidly going to destruction, and it is very desirable that steps be immediately taken to preserve these buildings or a typical example of them before they are utterly destroyed.

One of these settlements, Kasaan, has already been made a national monument. Steps should be taken to preserve others.

Dr. T. T. Waterman was sent by the bureau to investigate the whole question—primarily to secure whatever vanishing ethnological data is still extant. He was instructed to gather information on the sym-

bolism of the totem poles, the character of the houses, distribution of clans, and whatever scientific data can be obtained from those still living who once inhabited these villages. This line of investigation appeals very strongly to the chief from his knowledge of the growth in interest of the Mesa Verde National Park. In 1908, when he began work on this park, only 25 tourists visited the Mesa Verde; this year, 1922, the number will reach 4,500. This shows a great growth of interest in the work being done there; and, as many tourists now seek Alaska in their summer vacation, one of these villages repaired would attract many visitors. It is proposed to continue this work next summer with an enlarged appropriation.

The work of the bureau in other lines has gone on with customary vigor. The chief has repeatedly emphasized the necessity of rescuing the linguistic and sociological data of those Indian stocks that are rapidly disappearing. It would be culpable if any of these languages should vanish completely without some record. Interest in the aborigines of this continent has greatly increased in the last years, especially on account of the stimulus of the movement called "See America First."

In addition to his purely administrative duties, considerable time has been devoted by the chief to researches in the field. This work was archeological in nature and a continuation of that of previous years, and was carried on in cooperation with the National Park Service of the Department of the Interior.

Two months were spent in the neighborhood of Far View House, the first pueblo discovered on the Mesa Verde National Park, six years ago. In the course of the work this fine ruin was thoroughly repaired and put in such condition that it will now resist the wear of the elements for several years. Ruins once repaired must be watched with care. On an average between 3,000 and 4,000 visitors, mainly tourists, visit the Mesa Verde National Park and examine the excavated ruins. Fifteen thousand visitors have already passed through Spruce-tree House and Cliff Palace, and the wear on the soft rock of which the ruins are made is beginning to show. Unless constant vigilance is exercised the walls will fall within a short time. Any deterioration ought to be repaired annually. Tourists are not now permitted to visit any of the ruins on this park without a guide, a regulation that has been strictly enforced during the past year.

Field work in May and June was devoted to excavating a ruin called Pipe Shrine House, situated to the south of Far View House. This was apparently a communal building, or one not inhabited, which was used by the people of the pueblo for sacred ceremonies. It would appear that Pipe Shrine House, so called, bears the same relationship to Far View House that the Lower House of the Yucca

National Monument does to the Upper. The great kiva at Aztec, in New Mexico, lately excavated, bears a somewhat similar relationship to the main ruin, and there are several of the Chaco Canyon ruins where similar conditions prevail.

The site of Pipe Shrine House when work began was a low mound covered with sagebrush with a saucerlike depression in the center, not unlike several others in the immediate vicinity of Far View House. The removal of vegetation and débris and an excavation of the rooms revealed a rectangular building 70 by 60 feet, with walls averaging one story high. It had indications of a lofty tower in the middle of the western side, which must have imparted to the building somewhat the appearance of a church steeple or the minaret of a mosque. The large room was situated in the center of the ruin, its floor being about 20 feet below that of the other rooms. This subterranean room is a kiva, but it differs from others of like type on the park in that it has no fireplace in the center of the floor, no ventilator or deflector, and has eight mural pilasters instead of six to support the roof. The fallen walls within showed indications of a great conflagration, the stones and adobe being turned red and the walls turned bright red by the great heat. On the floor of the kiva was an inclosure set off by a semicircular wall where the action of fire was particularly evident. In the inclosure were found many votive offerings, the most numerous of which were a dozen clay tobacco pipes of various shapes and sizes, one or two decorated on their exteriors. These pipes, which are the first ever found on the Mesa Verde, evidently had been smoked by the priests and then thrown into the shrine. Besides the pipes the shrine also contained several fine stone knives, small decorated clay platters, various fetishes, and other objects. Pipe Shrine House was entered on the south by two doorways, midway between which a large pictograph of a coiled serpent was incised on a large stone set in the wall. To the south of the building there was a plaza surrounded by a retaining wall and directly opposite one of the entrances there are aboriginal steps which lead to a rectangular shrine 4 feet in size, in which were found a number of water-worn stones surrounding a large stone image of the mountain lion. The contents of this shrine were replaced, the mountain lion left in his original position, and the inclosure covered with a netting to prevent the possible removing of the objects from their places. Other shrines and several stone idols of considerable size were found in the neighborhood. The idols found at Pipe Shrine House represent the snake, mountain lion, mountain sheep, and bird—an important discovery, as previously only one stone animal idol had been found at the Mesa Verde Park.

One of the most instructive experiences of the archeologist is to see a skeleton centuries old as it lies in the grave. One of the ancient people of Pipe Shrine House was left in a prepared chamber for tourists to inspect.

The cemetery lies on the southeast corner of this ruin, and in it were found several human burials from one of which a good skeleton was chosen to illustrate the manner of burial and the mortuary offerings. This skeleton was not removed from the grave but was surrounded by a stone wall forming a room, rectangular in shape, protected by a grating and a waterproof roof. Visitors may now see one of the skeletons of the race of cliff dwellers as he was placed in his grave more than 500 years ago; not a single bone has been moved from position. This is the first time in North American archeology that an effort has been made to protect an Indian skeleton in situ, and the success of the method is self-evident, judging from the comments of visitors.

The pipes found in the shrine of the kiva have suggested "Pipe Shrine House" as a name for the building. It seems to have been given up to the rites and ceremonies of the inhabitants of the neighboring Far View House.

The second ruin excavated at Mesa Verde was formerly the habitation of one clan or of one social unit composed of relatives on the mother's side, on which account this ruin was given the name "One Clan House." It is situated about one-eighth of a mile south of Pipe Shrine House and consists of a circular subterranean room or kiva of fine masonry surrounded by rooms for sleeping, others for grinding corn, and still others used as bins for corn or storage rooms. The kiva was the ceremonial or men's room.

One of the most instructive ruins excavated in 1922 is a round tower, 15 feet in diameter and 10 feet high, situated about 300 feet north of Far View House. In front of this tower were found three subterranean kivas under the fallen débris, in one of which were constructed walls of a square building, indicating secondary occupation, and erected after the abandonment of the kiva. This tower and accompanying kivas may be called Far View Tower, and the indications are that it was used for observations, particularly of the sun on the horizon at sunrise and sunset, in order to determine the time for planting and other dates important for an agricultural people. These towers were probably rooms for the worship of the sun and other sky gods.

Some distance north of Far View Tower there were discovered in the cedars a number of large stones arranged vertically in rows projecting 3 feet above the surface of the ground. Excavation showed that these megaliths were walls of buildings of anomalous character, indicating a new type of architecture on the Mesa Verde. This

ruin, "Megalithic House," was not completely excavated, but all the others were repaired, the tops of the walls being covered with cement to prevent future erosion.

An important collection made by the chief in the course of the summer's work contains many rare and unique specimens, an account of which will later be published in a report on the excavations.

During his work at the Mesa Verde the chief gave camp-fire talks in the special amphitheater constructed for that purpose by the superintendent of the park. The average attendance on these talks was about 40 each evening, and at times, as on a visit of a convention of teachers, there were 150 listeners. He also spent considerable time daily taking parties over the new work which he was doing in the neighborhood of Far View House.

Ever since 1917 the chief has been attempting to have the sites of three clusters of towers in Utah withdrawn from private ownership and made into a national monument, to be called Hovenweep National Monument. Various circumstances have made it impossible to bring this about. During the past summer, however, Mr. Hatze, a Land Office surveyor, determined the metes and bounds of these three clusters and later Doctor Fewkes visited them in order to determine their present condition. He found that a settler had filed claims on the neighboring land, the adjoining one-quarter mile section, and erected his cabin. Some of the cabins in the neighborhood have stones remarkably like those of the towers; in other words, the necessity for immediate action, if these towers are to be preserved for posterity, is apparent, and the land on which they are situated should be withdrawn from settlement and the buildings put under the care of proper authorities. The three groups are known as the Square Tower, the Ruin Canyon group; the Holly and Keeley Towers; and the large ruin at the head of the Cajon Mesa called Cool Spring House, on account of the fine water which is found in the cave back of the cliff house.

During the fiscal year Dr. John R. Swanton, ethnologist, was engaged in extracting the words from his Hitchiti texts and adding them to his dictionary on cards of the Hitchiti language, and in preparing a grammatical sketch of 75 pages based on this material and that collected by Dr. A. S. Gatschet.

Much time was devoted to transferring words to cards from his Alabama texts, and from material in Alabama secured through native informants, into an Alabama-English dictionary. The first 25 pages of a grammatical sketch of this language have also been completed.

A comparison has been made between the Natchez language on the one hand and Koasati and Hitchiti on the other, in order to establish the position of Natchez in the Muskhogean linguistic stock. This

has not yet been set down in full, but all of the essential points have been typewritten on cards.

A paper of 44 pages has been prepared in elaboration of some recent discoveries regarding the Siouan peoples, discoveries which have an especial bearing on the relationship of the various Siouan groups to one another.

A small amount of work has been done in continuance of Doctor Swanton's investigations into the economic basis of American Indian life, particularly a study of aboriginal trails and trade routes.

The work of collecting stories dealing with the old clan divisions of the Chickasaw Indians, undertaken by a Chickasaw at Doctor Swanton's suggestion, has met with gratifying success, 10 or 12 such stories having already been sent in.

During the fiscal year Mr. J. N. B. Hewitt, ethnologist, was engaged entirely in office work.

In his report for the fiscal year 1921 it was stated that a number of Chippewa and Ottawa texts had been obtained in 1900 from Mr. John Miscogeon, an Ottawa mixed blood, then in Washington, D. C., and that Mr. George Gabaoosa, a mixed-blood Chippewa, had been employed to amend and to supply the Chippewa versions of these texts. He also amplified the texts by substantial additions. This material covers 125 pages. Mr. Gabaoosa's fixed habit of writing his native language by means of the alphabet employed by the missionaries made it needful that these texts thus written be translated into the alphabet devised by Maj. J. W. Powell, founder of the Bureau of American Ethnology, for recording native Indian languages. This work of transliteration is one of considerable difficulty, because the aid of a native Chippewa speaker is not available in the office and Mr. Hewitt does not speak Chippewa.

In addition, Mr. Hewitt continued work in preparing the Muskhogean material detailed in his last report.

Mr. Hewitt also continued his typing of the native Onondaga texts of the second part of the Iroquoian Cosmology, the first part having appeared in the twenty-first annual report of the bureau. There are now 255 pages of text material in final form.

As custodian of manuscripts Mr. Hewitt reports that no new linguistic records were added to the material permanently in his charge. Collaborators and others make temporary deposits of manuscripts upon which work is being done, and these are not catalogued as of permanent deposit.

Mr. Hewitt spent much time and study in the preparation of data for official replies to correspondents of the bureau and of the Indian Office also, the latter by reference only. The scope of the inquiries covers almost the entire range of human interest, often quite outside of the specific researches properly coming within the activities of the

Bureau of American Ethnology, but many are only requests for the derivation of some alleged native Indian place or proper name, often greatly Anglicized and mutilated. Some of these inquiries require more than a day's work to answer, as it is sometimes necessary to visit the Congressional Library in search of data. Data for more than 75 such inquiries were prepared.

Immediately following the death of the late Mr. James Mooney, Mr. Hewitt assisted Mrs. Mooney in assorting and separating the personal letters and papers of Mr. Mooney, some in advanced stages of preparation (the accumulation of more than 30 years' activity in an official capacity), from those which by their nature are official documents, and correspondence and photographs. More than a week was devoted to this work.

Before placing this material in the new store-room a rough classification was made of it. Five main groups were made, corresponding roughly with the five chief papers which Mr. Mooney had under way for a number of years before his demise, namely, (*a*) A Study of the Peyote and Its Accompanying Religious Cult; (*b*) A Monograph on the Population of the Indian Tribes When First Known; (*c*) A Paper on Cherokee Medical Formulas Recorded in the Sequoya Alphabet by Native Priests; (*d*) Kiowa Heraldry; and (*e*) A Study of the Cheyenne and Arapaho Shields. Owing to the peculiar chirography of Mr. Mooney and his excessive use of abbreviations peculiar to himself, this task proved to be a most tedious and difficult one.

Mr. Hewitt, who represents the Smithsonian Institution on the United States Geographic Board, attended all its regular meetings except one and all the special meetings of the board.

Mr. Francis La Flesche, ethnologist, continued during the fiscal year the task of assembling his notes for the second volume of his work on The Osage Tribe. The manuscript for the second volume, which embraces two versions of an ancient Osage ritual entitled, "No^{n}-zhi^{n}-zho^{n} Wa-tho^{n}," Songs of the Rite of Vigil, was completed and turned in to the bureau on February 25, 1922, where it awaits publication.

The first version of this ritual, which is counted as next in importance to the Hearing of the Sayings of the Ancient Men, published in the thirty-sixth annual report of the bureau, was given by Wa-xthí-zhi of the Puma gens of the Osage. This man had learned the ritual from his father, Wa-thú-ts'aga-zhi, who is said to have been one of the best informed No^{n}'-ho^{n}-zhi^{n}-ga in the tribal rites. With some difficulty Mr. La Flesche managed to persuade Sho^{n}'-ge-mo^{n}-i^{n}, of the Peacemaker gens, a more conservative man than Wa-xthí-zhi, to give the second version, which belongs to his gens. As this ritual pertains to war, old Sho^{n}'-ge-mo^{n}-i^{n} desired it to be clearly

understood that his gens performed the ceremonies of the ritual as a mere matter of form rather than as an actual owner of the rite. The office of his gens, he explained, was one that was instituted for the conservation of life and the maintenance of peace within the tribe and with other tribes not related to the Osage.

On the completion of the manuscript for the second volume, Mr. La Flesche began the task of assembling his notes for the third volume, which will embrace two tribal rituals, the first of which is entitled "Wa-xó-be A-wa-thoⁿ," Songs Relating to the Wa-xó-be. The Wa-xó-be is the sacred hawk, the symbol of the valor of the Osage warrior. The second ritual is entitled "Çá Tha-dse Ga-xe," literally, The Making of the Rush, but meaning the Making of the Woven Rush Shrine for the Wa-xó-be.

On July 1, 1921, Dr. Truman Michelson, ethnologist, was at Tama, Iowa, continuing his work among the Fox Indians of that State. He completed gathering data on Fox mortuary customs and beliefs and restored texts appertaining to these and worked out a vocabulary as far as possible in the field. On the completion of this he restored phonetically a text previously collected on the Fox society known as "Those who worship the little spotted buffalo." He also worked out, as far as practical, the vocabulary to this text. At the close of August he returned to Washington and elaborated the material collected in the field. During the fiscal year Dr. Michelson submitted two manuscripts for publication, namely, "Notes on Fox mortuary customs and beliefs" and "Notes on the Fox society known as 'Those who worship the little spotted buffalo.'"

On May 25 Doctor Michelson left for the West to conduct researches among the Algonquian Indians of Iowa, Kansas, and Oklahoma. He stopped at Columbus, Ohio, to consult with Prof. L. Bloomfield. As a result of this conference it became apparent that Menomini is very clearly more closely related to Cree than to any other Algonquian language. He found the work at Shawnee, Okla., very difficult and expensive, owing to the fact that the Algonquian Indians of that State are scattered and distances are very great. However, during his short stay he secured sufficient information to show definitely that not only the Sauk but also the Kickapoo share many mortuary customs and beliefs with the Fox of Iowa. He thinks that these correspondences are too detailed and too numerous to be of independent origin and must be due to dissemination. This point regarding the Sauk and Fox is not novel, but it is regarding the Kickapoo. There are, however, some differences in the mortuary customs of all neighboring tribes. This last fact is not so well known. A detailed study of all three neighboring tribes, Siouan as well as Algonquian, on these matters alone can clear up the history of the

borrowings. He expects to obtain data on these points regarding the Shawnee and Potawatomi also.

The beginning of the fiscal year found Mr. J. P. Harrington, ethnologist, engaged in completing his bulletin on the Kiowa language, in several respects one of the most remarkable of the American Indian tongues. Aside from the phonetic system, with its unusual frequency of long vowels and diphthongs, we may point to the noun, several declensions of which form the singular by adding the same suffixes which other declensions use for forming the plural. These singulars of plural form are doubtless conceived as collective, for a personal pronoun in apposition also has the plural form. Thus pronominal agreement arises many times more complicated than that in the three-gendered languages of Europe, and is further involved by subjective, objective, and indirective pronouns largely combining to form a single syllable—a very terse yet involved system of speech. A number of Kiowa and Tanoan songs were found to have the melody following in exaggerated form the intonation of the spoken language. Thus the song "agoyopovi navi ha, wimbo winda" has the high tones of its words also high pitched in the song. This has led to the important discovery that certain melodies in intoned languages may take their clue from the intonation of the words. The Kiowa vocabulary secured is quite complete and forms an interesting contribution to the study of the place names, animal names, and plant names adopted by a tribe when it leaves its old home and moves to a new region. Mr. Harrington proceeded at the close of July to California to continue his studies of the Indians of the Chumashan area of that State. This expedition proved fruitful in results beyond all expectation. Special emphasis was laid on the place names, material culture, and language. More than 300 photographs of Indian places and historic landmarks were secured, together with a wealth of highly interesting and important data. The collecting of Indian place names in the Eastern States was neglected until too late, so that we have only a few names in distorted spelling and of uncertain etymology. It is still possible to obtain full data in many parts of the West, and there is scarcely any work which the Bureau can undertake which is more important or urgent, either in popular interest or as a help to the future ethnologist, historian, or archeologist.

Linguistic study is peculiarly important in this area, since it resurrects past culture and records perishing material for comparison with remote languages. Thirty new Ventureño songs were obtained from one singer, all with native words. The technique of the split-stick accompaniment and the dance steps were faithfully studied and the words were exhaustively compared with the corresponding prose forms.

Mr. Harrington's opinion was confirmed that the southern California culture has many curious points of resemblance with that of the Southwest. Even the Pueblo plumed prayer stick, with sand paintings and the ceremonial use of meal and seeds, have been found also among the Californians.

Twice during the fiscal year Mr. Harrington was temporarily transferred to the Department of the Interior for special archive work. At the close of the fiscal year he returned to Washington.

SPECIAL RESEARCHES.

During the past fiscal year Miss Densmore has extended her study of Indian music by recording songs among the Yuma, Cocopa, and Yaqui tribes, making a total of nine tribes among whom this work has been done. Mohave songs were obtained from two members of that tribe living on the Yuma Reservation, and one Maya song was recorded in the Yaqui village. Four manuscripts on Indian music were submitted, the titles being "Songs Concerning Elder Brother and His People, and Other Papago Songs," "The Rain Ceremony of the Papago," "A Cocopa Legend and its Songs," and "Deer Dance Songs of the Yuma, Yaqui, and Maya Indians." In addition to her work on Indian music Miss Densmore has completed for publication two books on Chippewa culture with the titles "Uses of Plants by the Chippewa," and "Chippewa Arts and Customs." The former book contains descriptions of the uses of 168 plants in medicine, food, dye, charms, and general utility, the section on medicine being in tabulated form and showing the uses of the plant by other tribes, where such use is recorded, and its use by the white race, if such occurs. This tabulation shows the ailments for which a plant was used, the part of the plant utilized, the manner of its preparation, the dosage, and, in some instances, the time before an improvement in the condition of the patient was expected. The latter book contains sections on Chippewa nouns and their structure, on the various industries by which the tribe maintained itself, and on the care and training of little children. New material was submitted in the form of two manuscripts, Certain Customs of the Chippewa in Ontario, Canada, and Chippewa Nouns and Their Structure, these titles corresponding to the principal subjects under consideration. Three brief trips in Minnesota and Wisconsin were made for this work. Miss Densmore also read the page proof of her book on Northern Ute Music.

In February, 1922, Miss Densmore went to Yuma, Ariz., where she remained six weeks. During that time she made a brief trip to a Cocopa settlement located near the Colorado River and about 6 miles from the Mexican boundary. The older Cocopa living

at this point came from Mexico about 18 years ago and neither they nor their children had a status in the United States. At this time, however, they were enrolled under the Yuma Agency, Miss Densmore assisting in the enrollment by writing their Cocopa names in simple phonetic spelling. Forty Cocopa songs were recorded, comprising songs of two representative dances and of a cremation legend. For this work it was necessary to employ two interpreters.

It is the custom of both Cocopa and Yuma to cremate their dead, and Miss Densmore witnessed a Yuma cremation soon after her arrival. The dead man had been a leading singer at cremations and the ceremony was given with the elaborateness which would be accorded a chief. The songs were very old and are seldom used at the present time. Miss Densmore obtained phonographic records of these songs, as well as of the Kurok or Memorial ceremony which is held each summer for the more important persons who have died during the year. Images of the deceased persons are carried in the dances of the Kurok and publicly burned. The history of these ceremonies, with the songs, was obtained from the oldest man who is an authority on the subject. It is the belief of these people that the spirit departs from the body in the flame of the cremation.

A new musical form was found among the Yuma and Cocopa, consisting of a "song cycle" which required an entire night for its rendition and is commonly called a "story." Each of these stories has its designated accompaniment. Among the Yuma the accompanying instruments are a gourd rattle and an inverted basket struck with a bundle of arrow-weed, a willow stick, or the palm of the hand. Sometimes two bundles of arrow-weed or two willow sticks are used, being held in the same hand. Specimens of these instruments were obtained, also a bamboo flute and two bamboo flageolets. The music of the latter was phonographically recorded. The Yuma songs included those of the treatment of the sick, those of games, and three interesting lullabies.

The work among the Yaqui was conducted at Guadalupe village, near Tempe, Ariz. The older Yaqui in this village were born in Mexico. These Indians have received no favors from the United States Government and support themselves by manual labor. They seem happy and contented in their little desert village. Miss Densmore witnessed their deer dance and later recorded the songs from one of the leading singers, a native of Mexico. The occasion of the dance was the celebration of Easter eve. The songs were accompanied by playing upon four half gourds. The Yaqui have two distinct forms of music, one which appears to be entirely native and the other showing a Mexican or Spanish influence.

A large proportion of the songs transcribed and heard during the past year were accompanied by a gourd rattle, and are of unusual

musical value, both in pleasing melody and rhythmic interest. This suggests an inquiry as to whether the songs accompanied by the rattle are generally more musical than those accompanied by the drum. It is interesting to note that the songs of the Yuma and Cocopa resemble each other but differ entirely from the songs of the Papago who live adjoining them. The songs of the Yaqui, so far as observed, differ from both these tribes except in the frequent use of rests. The rhythm of the rattle in Yuma and Cocopa performances is more elaborate and contains more frequent changes than that of the accompanying instrument in any tribe thus far studied. A correspondence between the words of the song and the progressions of the melody is particularly evident in these songs.

Early in March, 1922, Dr. T. T. Waterman, ethnologist, proceeded to Alaska, under temporary appointment in the bureau, with instructions from the chief to scrutinize certain native towns in southeastern Alaska. His purpose was to ascertain how many totemic monuments exist there, and to get information concerning the carvings. The place of special interest was a former settlement of Alaskan Haida, known as Kasaan. It was possible during the three months that Doctor Waterman spent in Alaska to make a rapid survey not only of Kasaan but of the towns known as Village Island, Tongass, Cape Fox, Klinkwan, Howkan, Sukwan, Klawak, and Tuxekan. Some extremely interesting monuments, including many tall and imposing totem poles, were examined and photographed. Charts or sketch maps were brought back from the field, which show the number of monuments still standing in each town and their state of preservation. The observer was fairly successful in obtaining from the Indians an account of the meaning of the carvings on the poles, which have never been adequately described. In many cases the carvings refer to mythical tales, which are often of a very interesting type.

In addition to the work on the totemic monuments, the observer recorded a relatively complete list of the native place names in the southeastern part of Alaska. Many hundreds of these names were entered on the map of the region, and translations and explanations were obtained from the Indians. The work was fairly complete for the area covered.

Under further instructions from the chief, Doctor Waterman examined the coast line of the part of Alaska which he visited, with a view to discovering sites where archeological excavations might possibly be conducted. The results of this work were largely negative. As a matter of fact only one site was found where there seemed to be archeological remains. This hasty survey seemed to indicate that archeological remains in this part of Alaska are extremely scanty.

Returning to the bureau on June 15, Doctor Waterman began the preparation of a report on the Alaskan monuments.

In the fall of 1921, Mr. W. E. Myer investigated sites in South Dakota and western Missouri, known to have been occupied by the Omahas and Osages in early historic times, after they had come in contact with the whites but before they had been changed thereby to any considerable extent.

Especial attention was paid to any resemblance to the ancient cultures found in the valleys of the Ohio, Cumberland, and Tennessee Rivers. This line of research was suggested by certain traditions of both the Omahas and the Osages, and other branches of the great Siouan linguistic family, that they had at one time lived east of the Mississippi River, and after many wanderings, stopping here and there for years, finally reached their present homes in South Dakota and western Missouri.

Mr. Francis La Flesche reported that the traditions of his people, the Omahas, were that they had occupied two important villages on what the Omahas call "The Big Bend of the Xe," at some time in the seventeenth or eighteenth century.

Mr. Myer was enabled to locate these two ancient villages; one, Split Rock site on the Big Sioux River, at its junction with Split Rock River; the other where the Rock Island Railroad now crosses the Big Sioux River, about 10 miles southeast of Sioux Falls. It is here designated the Rock Island site.

Sometime in the seventeenth century the Omahas and Poncas removed from the Pipestone region in Minnesota and finally, after some further wanderings, built a fortified town on the Rock Island site. While living in this fortified place they were attacked and defeated by an enemy, most probably the Dakotas, and finally forced to leave the region. There is a tradition that they buried their dead from this fight in a mound. This tradition was confirmed by excavations made by Mr. A. G. Risty and Mr. F. W. Pettigrew, who report finding a considerable amount of human bones. Some glass beads and small copper bells of white man's make were also found in one of these mounds. There is evidence that this site was occupied somewhere between 1700 and 1725.

After leaving the Rock Island site, the Omahas and Poncas roved without long permanent settlements for several years, but finally returned to the Xe and built a permanent village at Split Rock at the junction of the Big Sioux and Split Rock Rivers.

Mr. Myer spent the month of October, 1921, in exploring this Split Rock site. Many interesting relics of the Omahas were here unearthed, which throw new light on the life of these people before they had been very much changed by contact with the whites.

The 30 mounds on the ridge between the two rivers mark the site of that portion of the old town occupied by the Omahas. On a hill one-half mile to the east was a group of 10 more mounds, occupied by the Poncas before they split away from the Omahas.

By following the clues furnished by the traditions, three low mounds were discovered on the tall ridge 1½ miles to the west. These were said to have marked the lookouts for the main village; they command a view, ranging from 6 to 15 miles, on all sides. The mounds on the Split Rock site appear to have nearly all been used for burial.

The exploration of mound No. 1, on the Omaha section of the town, showed a beautiful little knoll on the edge of the steep, bluff-like bank of Split Rock River. In its soil the Indians dug a shallow pit, about 12 by 6 feet, and 2 feet deep. Here were placed bones belonging to five bodies, several of which appeared to have been buried after decay of the flesh. One body appeared to have been closely flexed before it was placed in the pit. The position of the skeleton of a horse with a crushed frontal bone showed that when this body bundle had been placed in the pit, a large horse, about seven years of age, had been led to the knoll, and there killed. Then, over all these, a low, round-topped mound, 60 feet across at the base and 5½ feet in height, had been raised.

Mound No. 2, the largest of the group, was round topped, 110 feet across at the base, and 10 feet high. A rectangular charnel pit, 12 by 14 feet and 2 feet deep, had been dug in the surface of the soil near the center of the town. This pit was thoroughly lined or coated with a white layer about one-eighth inch in thickness, made from calcined bones. The bottom and sides of the pit were then probably covered with furs, now indicated by a thin layer of animal matter on the white coating. Bones representing about 50 human beings had been laid on the floor of this fur-lined pit.

Traces of the thin fur layer were also found on top of this solid mass of human bones. Over this fur covering a layer of bark was placed, and upon this bark earth had been spread to a depth of from 3 to 6 inches. The earth was then smoothed and pressed down, and on this surface a white coating, similar to that on the bottom and sides, had been spread. Only one small, cylindrical copper bead was found with all this mass of bones, and no object of white man's manufacture was found. There is evidence that this portion of the site was occupied by the Omahas somewhere between 1725 and 1775.

While the Omahas and their kindred, the Poncas, lived together at the Split Rock site some of the most important events in their history took place. The united Omahas and Poncas and their old enemies, the Cheyennes and Arikaras, here made a peace which

was concluded with great ceremony. At the urgent request of the Arikara the sacred chant and dance of the calumet was used to cement this union.

In Vernon and Bates Counties, western Missouri, near the junction of the Osage and Marmiton Rivers, Mr. Myer found several sites known to have been occupied by the Osage Indians in early historic times, shortly after they had come in contact with the whites.

The largest Osage village in Vernon County was situated at Old Town, on Old Town Creek, about 3½ miles south of Pikes village of the Grand Osage. This site covers about 40 acres and is the best known of any of the Osage sites. It has yielded a large amount of iron axes, gun barrels, gunlocks, fragments of brass kettles, glass beads, and other articles of early white manufacture, as well as objects of purely aboriginal origin.

The most picturesque Indian site in this Osage region is Halleys Bluff, on the Osage River, about 1½ miles downstream from where the Marmiton and Marais des Cygnes unite to form the Osage River. There is evidence showing occupancy of this bluff by Indians long before the coming of the white man and probably before the coming of the Osages.

During the month of October, 1921, Mr. David I. Bushnell, jr., visited Scott Field, east of Belleville, Ill., for the purpose of getting airplane pictures of the Cahokia mounds. The commanding officer of the field, Maj. Frank M. Kennedy, appreciating the interest and importance of the work, detailed Lieuts. Harold R. Wells and Ashley C. McKinley, of the Air Service, to make the pictures. They succeeded in making some very interesting photographs of mounds in the vicinity of Cahokia, as well as of the great mound itself, but unfortunately the photographic apparatus at that time available at Scott Field was not suitable, and although the pictures obtained were not very clear, nevertheless no better results could have been secured with the cameras which they were obliged to use. Four of the pictures made by Lieutenants Wells and McKinley were reproduced as Figures 101, 102, 103, and 104 in Explorations and Field Work of the Smithsonian Institution in 1921 and should prove of special interest as the first photographs of American earthworks made from the air.

The article in which the four airplane pictures were used was prepared for the purpose of showing the great importance of the Cahokia group and of the other related groups to the north, west, and south of Cahokia. The southern group, although many of the units have been destroyed, is of special interest. It is situated near the left bank of the Mississippi, opposite Jefferson Barracks. Bits of pottery, chips of flint, and other traces of a settlement, together with stone-lined graves in the vicinity of the mounds, may indicate the position of a village of one of the Illinois tribes two centuries or more ago.

Mr. B. S. Guha's visit among the Utes and the Navaho at Towoac and Shiprock, respectively, during the summer of 1921 was undertaken primarily with the object of finding any legends or myths about the ancient Cliff Dwellers of Mesa Verde that might still survive among these people, and incidentally to collect as much material about their social institutions as possible.

Mr. Guha arrived at Towoac on July 14, 1921, and spent a couple of weeks visiting the different camps of the Utes. Among the Wiminuche Utes, unfortunately, there does not appear to survive any legends or myths about the Mesa Verde. All that could be gathered from the oldest living members of the tribe was that when their ancestors first came to the Ute Mountain from the north, the whole region from the La Plata to the Blue Mountains and from Dolores to the San Juan was full of ruins such as now may be seen. They were already abandoned, but there were signs of the cultivation of corn about them.

After leaving Towoac Mr. Guha went to Shiprock, N. Mex., and stayed there until September 5, 1921. Unlike the Utes, the Navaho seem to possess survivals of myths about the ancient Cliff Dwellers of Mesa Verde. How far these legends have any historical background it is difficult to say, but they at any rate suggest some earlier and closer relationhip between them and the people who lived in the ruins so liberally strewn over the entire region.

In September, 1921, Mr. John L. Baer, acting curator of American archeology in the United States National Museum, made an investigation for the bureau of pictographic rocks in the Susquehanna River. In the middle of the river between Bald Friar and Conowingo, Md., are a number of huge boulders of serpentine or gabbro, bearing inscriptions, a few of which have been heretofore described in the Tenth Annual Report of the Bureau of American Ethnology and in Volume CCC (Lancaster County), Second Geological Survey of Pennsylvania. The largest and most important of these pictographic rocks were found to be on Miles' Island at the head of Gray Rock Falls. Large surfaces of these rocks seem to have been polished before the figures were pecked upon them. Pits, grooved lines indicating tally marks, circles with radiating spokes, concentric circles, faces, and fishlike outlines were the prevailing figures observed.

Other groups of rocks between this island and Conowingo showed equally interesting carvings, but not so profusely. A pyramid-shaped rock standing well out in the rough and dangerous rapids had several fish outlined near its apex. A slab which had been broken from its original position and which might have been used for a shad-dipping stand, was marked with outlines of two slender

fish and two tally marks. A number of interesting photographs and drawings of these pictographs were secured.

In connection with a reconnoitering trip among the prehistoric quarries and workshops along the Susquehanna in the spring of 1922, Mr. Baer again visited these pictographic rocks and secured additional drawings and a number of plaster casts of the more important figures. Prehistoric steatite quarries were traced from the west side of the river at this point to Deer Creek in Harford County, Md. Those showing most work and offering best opportunities for investigation are near Broad Creek in woodland owned by James McLaughlin, near Robinson's mill, and by W. C. Heaps, Mill Green, Harford County, Md.

At a workshop below Peach Bottom, Lancaster, Pa., a number of unfinished and broken banner stones of prochlorite were found. The source of the material was located a short distance east of Bald Friar, Md. A large number of unfinished banner stones of slate were found at the workshop on Mount Johnson Island above Peach Bottom where so many specimens had already been found. At Fishing Creek, Bare Island, and Henry Island evidences were found of considerable camp sites. At New Park, and Fawn Grove in York County, Pa., have been found large caches of rhyolite blades. At both of these places and also at Peach Bottom in the same county were many artifacts and indications of burial grounds. Interesting specimens were secured from most of these localities.

EDITORIAL WORK AND PUBLICATIONS.

The editing of the publications of the bureau was continued through the year by Mr. Stanley Searles, assisted by Mrs. Frances S. Nichols. The status of the publications is presented in the following summary:

PUBLICATIONS ISSUED.

Thirty-fifth Annual Report. Accompanying paper: Ethnology of the Kwakiutl (Boas). Pts. 1 and 2. 1,481 pp.

Thirty-sixth Annual Report. Accompanying paper: The Osage Tribe: Rite of the Chiefs; Sayings of the Ancient Men (LaFlesche). 604 pp., 23 pls.

Bulletin 73. Early History of the Creek Indians and their Neighbors (Swanton). 492 pp., 10 pls.

Bulletin 74. Excavation of a Site at Santiago Ahuitzotla, D. F. Mexico (Tozzer). 56 pp., 19 pls.

Bulletin 75. Northern Ute Music (Densmore). 213 pp., 16 pls.

PUBLICATIONS IN PRESS OR IN PREPARATION.

Thirty-fourth Annual Report. Accompanying paper: A Prehistoric Island Culture Area of America (Fewkes).

Thirty-seventh Annual Report. Accompanying paper: The Winnebago Tribe (Radin).

Thirty-eighth Annual Report. Accompanying paper: An introductory Study of the Arts, Crafts, and Customs of the Guiana Indians (Roth).
Thirty-ninth Annual Report. Accompanying paper: The Osage Tribe: The Rite of Vigil (LaFlesche).
Bulletin 76. Archeological Investigations (Fowke).
Bulletin 77. Villages of the Algonquian, Siouan, and Caddoan Tribes west of the Mississippi (Bushnell).
Bulletin 78. Handbook of the Indians of California (Kroeber).
Bulletin 79. Blood Revenge, War, and Victory Feasts among the Jibaro Indians of Eastern Ecuador (Karsten).
Bulletin 80. Mandan and Hidatsa Music (Densmore).
Bulletin 81. Excavations in the Chama Valley, New Mexico (Jeancon).

DISTRIBUTION OF PUBLICATIONS.

The distribution of publications has been continued under the immediate charge of Miss Helen Munroe, assisted by Miss Emma B. Powers. Publications were distributed as follows:

Annual reports and separates	7,197
Bulletins and separates	6,403
Contributions to North American Ethnology	39
Introductions	13
Miscellaneous publications	563
	14,215

As compared with the previous year, there was an increase of 1,420 publications distributed. There was a decrease of 57 names in the mailing list.

ILLUSTRATIONS.

Mr. De Lancey Gill, illustrator, with the assistance of Mr. Albert E. Sweeney, continued the preparation of the illustrations of the bureau. A summary of this work follows:

Line and color drawings, including maps, diagrams, etc., intended for use as illustrations for publication	159
Illustrations, including photographs retouched, mounted, and made ready for engraving	1,282
Illustration proof edited	1,034
Lithographic proof examined at Government Printing Office	36,000
Photographic work, negatives of ethnologic and archeologic subjects	242
Films developed from field exposures	138
Prints for distribution and office use	538
Photostat copies	1,987

Mr. Sweeney was detailed for the month of June to prepare 100 or more negatives for the National Zoological Park.

LIBRARY.

The reference library continued in the immediate care of Miss Ella Leary, librarian, assisted by Miss Julia S. Atkins and Mr. Samuel H. Miller.

During the year 406 books were accessioned, of which 64 were acquired by purchase, 120 by binding of periodicals, and 142 by gift and exchange. The periodicals currently received number about 900, of which 33 are received by subscription, the remainder being received through exchange. The bureau has also received 159 pamphlets, giving at the close of the year a working library of 24,561 volumes, 14,936 pamphlets, and several thousand unbound periodicals.

In addition to the regular routine of library work, Miss Leary has been able, with the assistance of Miss Atkins, to make rapid progress toward the completion of the new subject catalogue, with the result that about 18,000 catalogue cards have been filed during the fiscal year.

The greatest need of the library is for more shelf room for its publications, due to its growth during the past few years. The library is greatly hampered by this need.

The posting of the monthly bulletin of new publications was continued throughout the year.

During the year many students not connected with the Smithsonian Institution found the library of service in seeking volumes not obtainable in other libraries of the city. The library was used also by the Library of Congress and officers of the executive departments, and out-of-town students have called upon the library for loans during the year. In addition to the use of its own library it was found necessary to draw on the Library of Congress from time to time for the loan of about 400 volumes.

There were bound during the year 200 books, pamphlets, and serial publications.

COLLECTIONS.

The following collections, acquired by members of the bureau or by those detailed in connection with its researches, have been transferred to the United States National Museum:

66880. Collection of Alaskan ethnologica made by the late Rev. Sheldon Jackson and purchased by the bureau from his daughter, Miss Leslie Jackson.

67105. Shell and pottery specimens from Ten Thousand Islands, Florida, collected during the spring of 1921 by Mr. William Dinwiddie, Metuchen, N. J.

67112. Four stone objects and two pottery fragments from "Bear" and "Lewis" mounds, near Portsmouth, Ky., collected by Mr. Gerard Fowke during the spring of 1921.

67225. Four pieces of pottery and eight pieces of flint, collected by Prof. J. E. Pearce, of Austin, Tex., in eastern Texas during the summer of 1919.

67258. Collection of shell objects presented to the bureau by Charles T. Earle, of Palma Sola, Fla., found near Shaws Point, Fla.

67274. Collection of archeological objects secured by Dr. J. Walter Fewkes from the Mesa Verde National Park, Colo., in the spring of 1920.

67898. Chunkey stone from Rowena, Ky.

67451. Archeological objects collected near Austin and at "Burnt Rock" mounds, Texas, by Prof. J. E. Pearce and Dr. J. Walter Fewkes.
67572. Collection of skeletal material secured by Mr. William E. Myer in the vicinity of the junction of Split Rock River and Big Sioux River, S. Dak.
67730. Archeological material collected in 1920 by Mr. W. E. Myer for the Bureau of American Ethnology in Williamson and Davidson Counties, Tenn.
68254. Collection of archeological objects from Rio Grande Valley, N. Mex., turned over to the bureau by Secretary Charles D. Walcott.
68255. Fragments of pottery from Indian burial on the Catawba River, N. C., sent to the bureau by J. Albert Holmes, Construction, N. C.
68256. Collection of Indian implements found on the terraces of Upatoi Creek, and Chattahoochee River, Muscogee County, Ga., sent to the bureau by Mr. A. T. Sweet, Columbus, Ga.

PROPERTY.

Furniture and office equipment were purchased to the amount of $134.97.

MISCELLANEOUS.

Clerical.—The correspondence and other clerical work of the office has been conducted by Miss May S. Clark, clerk to the chief. Mrs. Frances S. Nichols assisted the editor. Mr. Anthony W. Wilding served as messenger and typist to the chief.

Personnel.—Miss Julia S. Atkins received a permanent appointment as stenographer March 1, 1922.

Dr. T. T. Waterman, who was appointed as temporary ethnologist March 1, 1922, was detached from the bureau roll July 1 for six weeks in order to lecture in the summer school of Columbia University, New York City.

Mr. Samuel H. Miller, messenger boy in the library, resigned June 23, 1922.

Mr. James Mooney, ethnologist, died December 22, 1921.

Respectfully submitted.

J. Walter Fewkes,
Chief, Bureau of American Ethnology.

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 5.

REPORT ON THE INTERNATIONAL EXCHANGES.

SIR: I have the honor to submit the following report on the operations of the International Exchange Service during the fiscal year ending June 30, 1922:

The appropriation granted by Congress for the support of the service during the year was $50,000, the same as the amount for the year 1921. The excess of these appropriations over those formerly allowed for the system of international exchanges was designed to meet the extraordinary expenses of forwarding, at the high ocean and other transportation rates, the accumulations of packages that were withheld awaiting the resumption of shipments to certain foreign countries. In addition to the above appropriation, the usual allotment of $200 for printing and binding was allowed by Congress. The repayments from departmental and other establishments aggregated $5,510.74, making the total resources available for carrying on the system of exchanges for the year, $55,710.74.

During the year 1922 the total number of packages handled was 383,157, a decrease from the number for the preceding year of 68,314. These packages weighed a total of 592,600 pounds, a decrease of 12,712. While in consequence of the return to nearly normal conditions the figures just given show a falling off in the number and weight of packages passing through the service from those handled last year, the work during the fiscal year 1922 exceeded by 41,490 the number of packages handled in 1914, just prior to the World War, which indicates a steady increase in the work of the office.

The number and weight of the packages of different classes are given in the following table:

	Packages.		Weight.	
	Sent.	Received.	Sent.	Received.
			Pounds.	*Pounds.*
United States parliamentary documents sent abroad	133,363	.....	82,905	.....
Publications received in return for parliamentary documents	.....	2,687	.....	7,782
United States departmental documents sent abroad	128,755	.....	191,502	.....
Publications received in return for departmental documents	.....	7,111	.....	22,600
Miscellaneous scientific and literary publications sent abroad	82,730	.....	222,741	.....
Miscellaneous scientific and literary publications received from abroad for distribution in the United States	.....	28,511	.....	65,070
Total	344,848	38,309	497,148	95,452
Grand total	383,157		592,600	

It should be stated here that the disparity in the above figures between the number of packages sent and those received is accounted for in part by the fact that packages transmitted abroad often contain only one publication, while those received in return frequently comprise many volumes. In some instances, especially in the case of publications received in exchange for parliamentary documents, the term "package" is applied to large boxes containing many separate publications. Furthermore, many returns for publications sent abroad reach their destinations in this country through the mails and not through the exchange service.

I stated last year that the steps taken by the Institution looking to the reopening of exchanges with Rumania and the establishment of relations with the newly formed Government of Jugoslavia had not led to a successful result. The Governments of both those countries expressed a desire to have the shipment of international exchanges resumed as soon as conditions would permit, but nothing further was heard from either of them. An offer made during the latter part of the year by the Institutul Meteorologic Central, Bukharest, and the Académie Royale Serbe des Sciences et des Arts, Belgrade, to serve as agencies for their respective countries was therefore accepted by the Institution, and a shipment of 26 boxes was made to the former and 69 to the latter. The exchange agency in Rumania was formerly the Academia Romana and in Serbia the Ministère des Affaires Étrangères.

During the year exchange relations have been established with the newly formed Governments of Esthonia, Far Eastern Republic, Latvia, Lithuania, and Ukrainia.

The conditions in Russia and Turkey have not yet improved sufficiently to warrant the Institution in taking steps to renew the exchange of publications between those countries and the United States.

The Institution requested several New York forwarding agents to submit rates for handling and forwarding exchange consignments abroad, the rates to take effect on July 1, 1922. The proposal submitted by the present agents, Messrs. Davies, Turner & Co., 39 Pearl Street, New York City, was found to be the lowest, and shipments will therefore continue to be sent to foreign countries through that firm.

There were shipped abroad during the year 3,215 boxes, being an increase of 463 over the number for the preceding 12 months. This is the largest number of boxes forwarded through the exchange service in one year and is due in great measure to the opening of exchange relations with Jugoslavia and several of the independent Russian States, the packages for those countries having accumulated at the Institution for several years. The number of boxes shipped was fur-

ther augmented by the forwarding to Austria of a large number of United States patent specifications that were held during the war.

Of the total number of boxes sent abroad 394 contained full sets of United States official documents for foreign depositories, and 2,821 included departmental and other publications for depositories of partial sets and for miscellaneous correspondents.

It is gratifying to state that during the year the office has been able to return to its regular schedule of shipments to foreign countries. Consignments are now being forwarded to Great Britain and Germany weekly, to France and Italy semimonthly, and to all other countries monthly.

The number of boxes sent to each country is given in the following table:

Consignments of exchanges for foreign countries.

Country.	Number of boxes.	Country.	Number of boxes.
Argentina	119	Italy	121
Austria	203	Jamaica	3
Belgium	89	Japan	80
Bolivia	3	Latvia	12
Brazil	49	Netherlands	80
British Colonies	15	New South Wales	43
British Guiana	1	New Zealand	28
Bulgaria	9	Nicaragua	2
Canada	30	Norway	47
Chile	36	Paraguay	4
China	164	Peru	22
Chosen	1	Poland	49
Colombia	26	Portugal	22
Costa Rica	18	Queensland	17
Cuba	5	Rumania	32
Czechoslovakia	128	Salvador	4
Danzig	5	Siam	2
Denmark	41	South Australia	25
Ecuador	16	Spain	48
Egypt	11	Sweden	86
Esthonia	11	Switzerland	91
Far Eastern Republic	2	Syria	4
Finland	20	Tasmania	12
France	201	Ukrainia	2
Germany	523	Union of South Africa	30
Great Britain and Ireland	364	Uruguay	23
Greece	17	Venezuela	14
Guatemala	3	Victoria	50
Haiti	6	Western Australia	14
Honduras	2	Yugoslavia	69
Hungary	54		
India	7	Total	3,215

FOREIGN DEPOSITORIES OF UNITED STATES GOVERNMENTAL DOCUMENTS.

The number of sets of governmental documents forwarded abroad through the International Exchange Service to foreign depositories has been reduced during the year by one, the partial set formerly sent to Montenegro having been discontinued as that country is now a part of the Kingdom of the Serbs, Croats, and Slovenes, which receives a full set. The total number of sets of governmental documents distributed through the service is therefore 95, 57 full and 38 partial. The set sent to the Kingdom of the Serbs, Croats, and Slovenes is entered in the following list under Jugoslavia.

The name of the Austrian depository has been changed from the Statistische Zentral Kommission to the Bundesamt für Statistik.

A complete list of the depositories is given below:

DEPOSITORIES OF FULL SETS.

ARGENTINA: Ministerio de Relaciones Exteriores, Buenos Aires.
AUSTRALIA: Library of the Commonwealth Parliament, Melbourne.
AUSTRIA: Bundesamt für Statistik, Schwarzenbergstrasse 5, Vienna I.
BADEN: Universitäts-Bibliothek, Freiburg. (Depository of the State of Baden.)
BAVARIA: Staats-Bibliothek, Munich.
BELGIUM: Bibliothèque Royale, Brussels.
BRAZIL: Bibliotheca Nacional, Rio de Janeiro.
BUENOS AIRES: Biblioteca de la Universidad Nacional de La Plata. (Depository of the Province of Buenos Aires.)
CANADA: Library of Parliament, Ottawa.
CHILE: Biblioteca del Congreso Nacional, Santiago.
CHINA: American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.
COLOMBIA: Biblioteca Nacional, Bogotá.
COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
CUBA: Secretaria de Estado (Asuntos Generales y Canje Internacional), Habana.
CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.
DENMARK: Kongelige Bibliotheket, Copenhagen.
ENGLAND: British Museum, London.
FRANCE: Bibliothèque Nationale, Paris.
GERMANY: Deutsche Reichstags-Bibliothek, Berlin.
GLASGOW: City Librarian, Mitchell Library, Glasgow.
GREECE: Bibliothèque Nationale, Athens.
HAITI: Secrétaire d'Etat des Relations Extérieures, Port au Prince.
HUNGARY: Hungarian House of Delegates, Budapest.
INDIA: Imperial Library, Calcutta.
IRELAND: National Library of Ireland, Dublin.
ITALY: Biblioteca Nazionale Vittorio Emanuele, Rome.
JAPAN: Imperial Library of Japan, Tokyo.
LONDON: London School of Economics and Political Science. (Depository of the London County Council.)
MANITOBA: Provincial Library, Winnipeg.
MEXICO: Instituto Bibliográfico, Biblioteca Nacional, Mexico.

NETHERLANDS: Bibliotheek van de Tweede Kamer der Staten-Generaal, The Hague.
NEW SOUTH WALES: Public Library of New South Wales, Sydney.
NEW ZEALAND: General Assembly Library, Wellington.
NORWAY: Storthingets Bibliothek, Christiania.
ONTARIO: Legislative Library, Toronto.
PARIS: Préfecture de la Seine.
PERU: Biblioteca Nacional, Lima.
POLAND: Bibliothèque du Ministère des Affaires Etrangères, Warsaw.
PORTUGAL: Bibliotheca Nacional, Lisbon.
PRUSSIA: Preussische Staatsbibliothek, Berlin, N. W. 7.
QUEBEC: Library of the Legislature of the Province of Quebec, Quebec.
QUEENSLAND: Parliamentary Library, Brisbane.
RUSSIA: Public Library, Petrograd.
SAXONY: Oeffentliche Bibliothek, Dresden.
SOUTH AUSTRALIA: Parliamentary Library, Adelaide.
SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
SWEDEN: Kungliga Biblioteket, Stockholm.
SWITZERLAND: Bibliothèque Fédérale Centrale, Berne.
TASMANIA: Parliamentary Library, Hobart.
TURKEY: Department of Public Instruction, Constantinople.
UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.
URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
VENEZUELA: Biblioteca Nacional, Caracas.
VICTORIA: Public Library of Victoria, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
WURTTEMBERG: Landesbibliothek, Stuttgart.
YUGOSLAVIA: Ministère des Affaires Etrangères, Belgrade.

DEPOSITORIES OF PARTIAL SETS.

ALBERTA: Provincial Library, Edmonton.
ALSACE-LORRAINE: Bibliothèque Universitaire et Régionale de Strasbourg, Strasbourg.
BOLIVIA: Ministerio de Colonización y Agricultura, La Paz.
BRAZIL: Bibliotheca da Assemblea Legislativa do Estado do Rio de Janeiro, Nictheroy.
BREMEN: Senatskommission für Reichs- und Auswärtige Angelegenheiten.
BRITISH COLUMBIA: Legislative Library, Victoria.
BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.
BULGARIA: Ministère des Affaires Etrangères, Sofia.
CEYLON: Colonial Secretary's Office (Record Department of the Library), Colombo.
ECUADOR: Biblioteca Nacional, Quito.
EGYPT: Bibliothèque Khédiviale, Cairo.
FINLAND: Central Library of the State, Helsingfors.
GUATEMALA: Secretary of the Government, Guatemala.
HAMBURG: Senatskommission für die Reichs- und Auswärtigen Angelegenheiten.
HESSE: Landesbibliothek, Darmstadt.
HONDURAS: Secretary of the Government, Tegucigalpa.
JAMAICA: Colonial Secretary, Kingston.
LATVIA: Ministry of Foreign Affairs, Riga.

LIBERIA: Department of State, Monrovia.
LOURENÇO MARQUEZ: Government Library, Lourenço Marquez.
LÜBECK: President of the Senate.
MADRAS, PROVINCE OF: Chief Secretary to the Government of Madras, Public Department, Madras.
MALTA: Lieutenant Governor, Veletta.
NEW BRUNSWICK: Legislative Library, Fredericton.
NEWFOUNDLAND: Colonial Secretary, St. John's.
NICARAGUA: Superintendente de Archivos Nacionales, Managua.
NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.
PANAMA: Secretaria de Relaciones Exteriores, Panama.
PARAGUAY: Oficina General de Inmigracion, Asuncion.
PRINCE EDWARD ISLAND: Legislative Library, Charlottetown.
RUMANIA: Academia Romana, Bukharest.
SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.
SASKATCHEWAN: Government Library, Regina.
SIAM: Department of Foreign Affairs, Bangkok.
STRAITS SETTLEMENTS: Colonial Secretary, Singapore.
SWITZERLAND: Library of the League of Nations, Palace of Nations, Quai de Leman, Geneva.
UNITED PROVINCES OF AGRA AND OUDH: Undersecretary to Government, Allahabad.
VIENNA: Bürgermeister-Amt der Stadt Wien.

INTERPARLIAMENTARY EXCHANGE OF OFFICIAL JOURNALS.

The Library of the League of Nations, Geneva, Switzerland, and the Rügi Raamatukogu, Toompea, Reval, Esthonia, have been added to the list of those countries receiving the daily Congressional Record.

Mention was made in my last report of the fact that the Government of Poland had entered into the immediate exchange with the United States, although it had not signified its adherence to the Brussels convention providing for such exchange. During the year the Institution was advised through diplomatic channels that the Polish Government, in the exercise of the privilege granted to nonsignatory States by Article 2 of Exchange Convention B of March 15, 1886, had declared its adherence to that diplomatic instrument.

Following is a complete list of the addresses to which the daily Congressional Record is now sent:

ARGENTINA: Biblioteca del Congreso Nacional, Buenos Aires.
AUSTRALIA: Library of the Commonwealth Parliament, Melbourne.
AUSTRIA: Bibliothek des Nationalrates, Wien I.
BADEN: Universitäts-Bibliothek, Heidelberg.
BELGIUM: Bibliothèque de la Chambre des Représentants, Brussels.
BOLIVIA: Cámara de Diputados, Congreso Nacional, La Paz.
BRAZIL: Bibliotheca do Congresso Nacional, Rio de Janeiro.
BUENOS AIRES: Biblioteca del Senado de la Provincia de Buenos Aires, La Plata.
CANADA:
Library of Parliament, Ottawa.
Clerk of the Senate, Houses of Parliament, Ottawa.

COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
CUBA:
Biblioteca de la Cámara de Representantes, Habana.
Biblioteca del Senado, Habana.
CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.
DENMARK: Rigsdagens Bureau, København.
ESTHONIA: Rügi Raamatukogu, Toompea, Reval.
FRANCE:
Bibliothèque de la Chambre des Députés, au Palais Bourbon, Paris.
Bibliothèque du Sénat, au Palais du Luxembourg, Paris.
GREAT BRITAIN: Library of the Foreign Office, Downing Street, London, S. W. 1.
GREECE: Library of Parliament, Athens.
GUATEMALA: Biblioteca de la Oficina Internacional Centro-Americana, 8a Calle Poniente No. 1, Ciudad de Guatemala.
HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.
HUNGARY: Bibliothek des Abgeordnetenhauses, Budapest.
ITALY:
Biblioteca della Camera dei Deputati, Palazzo di Monte Citorio, Rome.
Biblioteca del Senato del Regno, Palazzo Madama, Rome.
LIBERIA: Department of State, Monrovia.
NEW SOUTH WALES: Library of Parliament, Sydney.
NEW ZEALAND: General Assembly Library, Wellington.
PERU: Cámara de Diputados, Congreso Nacional, Lima.
POLAND: Monsieur le Ministre des Affaires Etrangères, Warsaw.
PORTUGAL: Bibliotheca do Congresso da Republica, Lisbon.
PRUSSIA: Bibliothek des Abgeordnetenhauses, Prinz-Albrechtstrasse 5, Berlin, S. W. 11.
QUEENSLAND: The Chief Secretary's Office, Brisbane.
RUMANIA: Bibliothèque de la Chambre des Députés, Bukharest.
RUSSIA: Sendings temporarily suspended.
SPAIN:
Biblioteca del Congreso de los Diputados, Madrid.
Biblioteca del Senado, Madrid.
SWITZERLAND:
Bibliothèque de l'Assemblée Fédérale Suisse, Berne.
Library of the League of Nations, Geneva.
TRANSVAAL: State Library, Pretoria.
UNION OF SOUTH AFRICA: Library of Parliament, Cape Town.
URUGUAY: Bibliotheca de la Cámara de Representantes, Montevideo.
VENEZUELA: Cámara de Diputados, Congreso Nacional, Carácas.
WESTERN AUSTRALIA: Library of Parliament of Western Australia, Perth.
YUGOSLAVIA: Library of the Skupshtina, Belgrade.

The total number of copies of the daily Congressional Record set aside by law for exchange with foreign legislative bodies is 100. It will be seen from the above that this exchange is conducted with 44 establishments.

FOREIGN EXCHANGE AGENCIES.

It will be noted from the following list of exchange agencies that shipments are now being made to Esthonia, the Far Eastern Republic, Yugoslavia, Latvia, Lithuania, Rumania, and Ukrainia.

The Teachers' College at Vladivostok is the agency for the Far Eastern Republic; the Ministry of Foreign Affairs at Riga, for Latvia; the Académie Royale Serbe des Sciences et des Arts at Belgrade, for Yugoslavia; and the Institutul Meteorologic Central in Bukharest, for Rumania. Only a few packages have thus far been received for Lithuania, and, for the present, transmissions to that country will be made through the mails. Shipments were made to the university libraries at Dorpat and at Odessa, with the request that those libraries distribute the consignments and also act as the agencies for Esthonia and Ukrainia, respectively. As these shipments were not made until near the close of the year, replies have not yet been received from those establishments. It is anticipated, however, that both will consent to serve as exchange agencies.

A complete list of the foreign exchange agencies or bureaus is given below:

ALGERIA, *via* France.
ANGOLA, *via* Portugal.
ARGENTINA: Comisión Protectora de Bibliotecas Populares, Calle Cordoba 931, Buenos Aires.
AUSTRIA: Bundesamt für Statistik, Schwarzenbergstrasse 5, Vienna I.
AZORES, *via* Portugal.
BELGIUM: Service Belge des Echanges Internationaux, Rue des Longs-Chariots 46, Brussels.
BOLIVIA: Oficina Nacional de Estadística, La Paz.
BRAZIL: Serviço de Permutações Internacionaes, Bibliotheca Nacional, Rio de Janeiro.
BRITISH COLONIES: Crown Agents for the Colonies, London.
BRITISH GUIANA: Royal Agricultural and Commercial Society, Georgetown.
BRITISH HONDURAS: Colonial Secretary, Belize.
BULGARIA: Institutions Scientifiques de S. M. le Roi de Bulgarie, Sofia.
CANARY ISLANDS, *via* Spain.
CHILE: Servicio de Canjes Internacionales, Biblioteca Nacional, Santiago.
CHINA: American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.
CHOSEN: Government General, Keijo.
COLOMBIA: Oficina de Canjes Internacionales y Reparto, Biblioteca Nacional, Bogotá.
COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
CZECHOSLOVAKIA: Service Tchécoslovaque des Echanges Internationaux, Bibliothèque de l'Assemblée Nationale, Prague 1–79.
DANZIG: Stadtbibliothek, Danzig.
DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.
DUTCH GUIANA: Surinaamsche Koloniale Bibliotheek, Paramaribo.
ECUADOR: Ministerio de Relaciones Exteriores, Quito.
EGYPT: Government Publications Office, Printing Department, Bulaq, Cairo.
ESTHONIA: Negotiations to establish an agency now pending.
FAR EASTERN REPUBLIC: Teachers' College of the Far Eastern Republic, Vladivostok.
FINLAND: Delegation of the Scientific Societies of Finland, Helsingfors.

FRANCE: Service Français des Echanges Internationaux, 110 Rue de Grenelle, Paris.
GERMANY: Amerika-Institut, Universitätstrasse 8, Berlin, N. W. 7.
GREAT BRITAIN AND IRELAND: Messrs. Wheldon & Wesley, 2, 3, and 4 Arthur St., New Oxford St., London, W. C. 2.
GREECE: Bibliothèque Nationale, Athens.
GREENLAND, *via* Denmark.
GUADELOUPE, *via* France.
GUATEMALA: Instituto Nacional de Varones, Guatemala.
GUINEA, *via* Portugal.
HAITI: Secrétaire d'Etat des Relations Extérieures, Port au Prince.
HONDURAS: Biblioteca Nacional, Tegucigalpa.
HUNGARY: Dr. Julius Pikler, Fővárosi Telekértéknyilvántartó Hivatal (City Land Valuation Office), Központi Városház, Budapest III.
ICELAND, *via* Denmark.
INDIA: Superintendent of Stationery, Bombay.
ITALY: Ufficio degli Scambi Internazionali, Biblioteca Nazionale Vittorio Emanuele, Rome.
JAMAICA: Institute of Jamaica, Kingston.
JAPAN: Imperial Library of Japan, Tokyo.
JAVA, *via* Netherlands.
LATVIA: Ministry of Foreign Affairs, Riga.
LIBERIA: Bureau of Exchanges, Department of State, Monrovia.
LITHUANIA: Sent by mail.
LOURENÇO MARQUEZ: Government Library, Lourenço Marquez.
LUXEMBURG, *via* Germany.
MADAGASCAR, *via* France.
MADEIRA, *via* Portugal.
MOZAMBIQUE, *via* Portugal.
NETHERLANDS: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Académie technique, Delft.
NEW GUINEA, *via* Netherlands.
NEW SOUTH WALES: Public Library of New South Wales, Sydney.
NEW ZEALAND: Dominion Museum, Wellington.
NICARAGUA: Ministerio de Relaciones Exteriores, Managua.
NORWAY: Kongelige Norske Frederiks Universitet Bibliotheket, Christiania.
PANAMA: Secretaria de Relaciones Exteriores, Panama.
PARAGUAY: Servicio de Canje Internacional de Publicaciones, Sección Consular y de Comercio, Ministerio de Relaciones Exteriores, Asuncion.
PERU: Oficina de Reparto, Depósito y Canje Internacional de Publicaciones, Ministerio de Fomento, Lima.
POLAND: Bibliothèque du Ministère des Affaires Etrangères, Warsaw.
PORTUGAL: Secção de Trocas Internacionaes, Bibliotheca Nacional, Lisbon.
QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Office, Brisbane.
RUMANIA: Institutul Meteorologic Central, Ministerul Agriculturei, Bukharest.
RUSSIA: Shipments temporarily suspended.
SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.
SIAM: Department of Foreign Affairs, Bangkok.
SOUTH AUSTRALIA: Public Library of South Australia, Adelaide.
SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
SUMATRA, *via* Netherlands.
SWEDEN: Kongliga Svenska Vetenskaps Akademien, Stockholm.

SWITZERLAND: Service des Echanges Internationaux, Bibliothèque Fédérale Centrale, Berne.
SYRIA: American University of Beirut.
TASMANIA: Secretary to the Premier, Hobart.
TRINIDAD: Royal Victoria Institute of Trinidad and Tobago, Port-of-Spain.
TUNIS, via France.
TURKEY: Shipments temporarily suspended.
UKRAINIA: Negotiations to establish an agency now pending.
UNION OF SOUTH AFRICA: Government Printing Works, Pretoria, Transvaal.
URUGUAY: Oficina de Canje Internacional, Montevideo.
VENEZUELA: Biblioteca Nacional, Caracas.
VICTORIA: Public Library of Victoria, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
YUGOSLAVIA: Académie Royal Serbe des Sciences et des Arts, Belgrade.

RULES GOVERNING THE TRANSMISSION OF EXCHANGES.

A revised edition of the circular containing a brief description of the service and the rules under which packages are accepted for distribution, was published at the close of the year and is here reproduced for the information of any who may desire to make use of the service in the forwarding of publications.

In effecting the distribution of its first publications abroad, the Smithsonian Institution established relations with many foreign scientific societies and libraries, by means of which it was enabled to materially assist institutions and individuals of this country in the transmission of their publications abroad, and also foreign societies and individuals in distributing their publications in the United States.

In more recent years the Smithsonian Institution has been charged with the duty of conducting the official exchange bureau of the United States Government, through which the publications authorized by Congress are exchanged for those of other Governments; and by a formal treaty it acts as intermediary between the learned bodies and scientific and literary societies of this and other countries for the reception and transmission of their publications.

Attention is called to the fact that this is an international and not a domestic exchange service, and that it is designed to facilitate exchanges between the United States and other countries only. As publications from domestic sources for addresses in Hawaii, the Philippine Islands, Porto Rico, and other territory subject to the jurisdiction of the United States do not come within the designation "international," they are not accepted by the Institution for transmission through the service.

Packages prepared in accordance with the rules enumerated below will be received by the Smithsonian Institution from individuals or institutions of learning in the United States and forwarded to their destinations abroad through the various exchange bureaus or agencies in other countries. Many of these bureaus and agencies will likewise receive from correspondents in their countries such publications for addresses in the United States and its dependencies as may be delivered to them under rules similar to those prescribed herein, and will forward them to Washington, after which the Institution will transmit them to their destinations by mail free of cost to the recipients.

On the receipt of a consignment from a domestic source it is assigned a "record number," which number is, for identification purposes, placed on each package contained therein. After the packages have been recorded they are packed in boxes with consignments from other senders and are forwarded by freight to the bureaus or agencies abroad which have undertaken to distribute exchanges in those countries. To Great Britain and Germany shipments are made weekly, to France and Italy semimonthly, and to all other countries consignments are forwarded at intervals not exceeding one month.

The Institution assumes no responsibility in the transmission of packages intrusted to its care, but at all times uses its best endeavors to forward exchanges to their destinations safely and as promptly as possible. Especial attention should be called in this connection to the time ordinarily required for packages sent through the exchange service to reach their destinations. To Great Britain and Germany, for example, where weekly shipments are made, the average time for a package to reach its destination is about six weeks. In some instances the period is much shorter and in no case should it be longer unless there is some unavoidable delay at the ports of embarkation or debarkation. To those countries to which shipments are made at semimonthly and monthly intervals, the time of delivery is of course somewhat longer, depending on the distance and also whether packages are received at the Institution immediately before or after a shipment. If, therefore, advance notices are mailed by senders, mention should be made of the above facts in order that consignees may expect some delay between the receipt of notices and the arrival of packages. In cases where greater dispatch is desired, publications should be forwarded by the senders to their foreign destinations direct by mail.

RULES.

The rules governing the Smithsonian International Exchange Service are as follows:

1. Consignments from correspondents in the United States containing packages for transmission abroad should be addressed—"Smithsonian Institution, International Exchanges, Washington, D. C.," and forwarded with carriage charges to Washington prepaid.

2. In forwarding a consignment the sender should mail a letter to the Institution, stating by what route it is being shipped, and the number of boxes or parcels which it comprises. A list giving the name and address of each consignee should also be furnished. This request should invariably be complied with for record.

3. Packages should be legibly and fully addressed, using, when practicable, the language of the country to which they are to be forwarded. In order to avoid any possible dispute as to ownership, names of individuals should be omitted from packages intended for societies and other establishments.

4. Packages should be securely wrapped and cardboard used if necessary to protect plates from crumpling.

5. Letters are not permitted in exchange packages.

6. If donors desire acknowledgments, packages may contain receipt forms to be signed and returned by the establishment or individual addressed. Should publications be desired in exchange, a request to that effect may be printed on the receipt form or on the package.

7. The work carried on by the International Exchange Service is not in any sense of a commercial nature, but is restricted to the transmission of pub-

lications sent as exchanges or donations. Books sold or ordered through the trade are, therefore, necessarily excluded.

8. Specimens are not accepted for distribution, except when permission has been obtained from the Institution.

Respectfully submitted.

C. G. Abbot,
Assistant Secretary,
In Charge of Library and Exchanges.

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 6.

REPORT ON THE NATIONAL ZOOLOGICAL PARK.

SIR: I have the honor to present the following report on the operations of the National Zoological Park for the fiscal year ending June 30, 1922:

The appropriation allowed by Congress in the sundry civil act approved March 4, 1921, for the regular maintenance of the park was the same as for the preceding year, $125,000, with the usual additional allotment of $200 for printing and binding. The sum of $2,500, together with an unobligated balance of $2,403.66 left from the appropriation for alteration of boundaries, 1921, was also made available, as a continuing appropriation, for the purchase of land to correct the eastern boundary line near the Adams Mill Road entrance.

The year has been one of the most successful in the history of the park. A number of minor permanent improvements have been completed, progress has been made on some larger undertakings, and the grounds have been maintained in a condition gratifying to all who are interested in the great natural beauty of the reservation. At the close of the year the collection is larger, and of more importance, than ever before; more different species are on exhibition, and the actual number of animals is greater than in any previous year; there are more than the usual number of rare and valuable specimens; the births have been numerous; and the death rate has been kept at a low mark. For the third successive year the attendance has exceeded 2,000,000.

ACCESSIONS.

Gifts.—No less than 217 animals, an unusual number, were added to the collection as gifts, or were placed by friends of the park on indefinite deposit. Special mention in this connection should be made of two important collections from South America.

The collections of living animals made by Dr. William M. Mann on the Mulford Biological Exploration of the Amazon Basin reached the park on April 15, 1922. Included were 15 mammals, 50 birds, and 17 reptiles that arrived in perfect condition, and a very few others lost from the effects of travel. These were all generously presented to the park by the H. K. Mulford Co., of Philadelphia.

Doctor Mann is to be congratulated on his success in bringing to the country live representatives of several species from Bolivia and western Brazil that have never before been shown. The red-faced spider monkey, black-headed woolly monkey, pale capuchin, choliba screech owl, Bolivian penelope, short-tailed parrot, Maximilian's parrot, blue-headed parrot, Cassin's macaw, golden-crowned paroquet, Weddell's paroquet, orange-winged paroquet, and golden-winged paroquet are new to the collection. These and other rarities are mostly from the Rio Beni, Bolivia, and the upper Rio Madeira, Brazil, localities from which animals seldom find their way into collections. Other species, including such rare birds as the festive parrot, Amazonian caique, and white-backed trumpeter, while not new to the park records, are unusual. There were also some showy birds and small mammals from the lower Amazon as well as an excellent collection of living reptiles. On account of the great proportion of rare species it contained and the unusually good condition of the specimens on arrival, the Mulford Explorations collection easily ranks as the most important accession received from tropical America in some years.

Mr. W. J. La Varre, jr., continuing his donations from personal exploration of out-of-the-way parts of South America, presented 28 birds and mammals from the interior of British Guiana. Conspicuous among these are a cock of the rock, a Hahn's macaw, and two dusky parrots, all new to the collection. Mr. La Varre also succeeded in landing a young red howler monkey. The cock of the rock, a young bird in immature plumage on arrival, has now developed into full color and is one of the most showy and attractive exhibits in the bird house.

Mr. Victor J. Evans, of Washington, D. C., long a regular contributor to the collection, purchased and placed on indefinite deposit a Cape great-eared fox and two yellow-billed hornbills, both species new to the records of the park. The long-eared fox, received from South Africa, is doubtless the first representative of its species ever exhibited alive in America.

Sixty-eight individual donors contributed to the collection during the year. The complete list is as follows:

Mrs. Benjamin E. Abbott, Washington, D. C., Virginia opossum.
Dr. Arthur A. Allen, Ithaca, N. Y., 10 greater scaup ducks.
American Express Co., Washington, D. C., 4 chipmunks.
Mrs. R. P. Andrews, Washington, D. C., Cuban parrot.
Mr. Carl Bandrexler, Washington, D. C., copperhead.
Mr. Murrell Barkley, Washington, D. C., 2 tovi paroquets.
Mrs. A. H. Baum, Washington, D. C., alligator.
Mrs. William R. Bedell, Washington, D. C., blue-fronted parrot.
Mr. John M. Blanton, Washington, D. C., Texas red wolf.
Mrs. Grace Boone, New Midway, Md., American coot.

Mr. M. G. Butler, Dillwyn, Va., great horned owl.

Mr. Thomas F. Callahan, Washington, D. C., great horned owl.

Canadian Government, through Hon. J. B. Harkin, yak.

Mr. Madison Clark, Washington, D. C., great horned owl.

Mrs. John L. Clem, Washington, D. C., zebra finch.

Mr. M. Cochrane, La Plata, Md., American barn owl.

Mr. N. B. Davis, Washington, D. C., alligator.

Mr. Harrison H. Dodge, Mount Vernon, Va., red and blue and yellow macaw.

Miss Josephine Duffey, Alexandria, Va., crab-eating macaque.

Mr. J. H. Evans, Washington, D. C., skunk.

Mr. Victor J. Evans, Washington, D. C., great-eared fox and two yellow-billed hornbills.

Commander Frank Jack Fletcher, United States Navy, Washington, D. C., grass paroquet.

Mrs. Kenneth L. Frye, Chevy Chase, Md., sulphur-crested cockatoo.

Mr. H. C. Fuller, Washington, D. C., brown capuchin.

Mrs. E. W. Gibb, Washington, D. C., raccoon.

Gude Bros. Co., Washington, D. C., alligator.

Miss Emma T. Hahn, Washington, D. C., 4 canaries.

Hon. Warren G. Harding, White House, Washington, D. C., coyote.

Mr. Mitchell Harrison, Nokesville, Va., raccoon.

Mr. Caleb R. Hathaway, Chevy Chase, Md., Virginia opossum.

Mr. Odis B. Hinnant, Washington, D. C., banded rattlesnake.

Mr. Allen Hoover, Washington, D. C., two alligators.

Mr. M. A. Horner, Seward, Alaska, Alaskan bald eagle.

Mr. S. F. Howland, Silver Springs, Md., barred owl.

Kazim Temple, A. A. O. N. M. S., Roanoke, Va., bald eagle.

Mr. R. A. Kishpaugh, Fredericksburg, Va., two alligators.

Mr. S. Seibert Knode, Boonsboro, Md., red-tailed hawk and two American barn owls.

Mr. W. J. La Varre, jr., Washington, D. C., red howler monkey, cock of the rock, Hahn's macaw, 2 dusky parrots, 3 orange-winged parrots, and 20 blue-winged parrotlets.

Mr. Harry L. Light, Washington, D. C., festive parrot.

Mr. Edward Lucas, Silver Springs, Md., jumping mouse.

Dr. C. L. Marlatt, Washington, D. C., yellow-headed parrot.

Dr. C. B. Masson, Washington, D. C., one black snake and five copperheads.

Mr. Richard McCann, Washington, D. C., woodchuck.

Mr. Edward B. McLean, Washington, D. C., kinkajou and brown pelican.

Miss Sara G. Meetze, Washington, D. C., red fox.

Mrs. Charles Middleton, Silver Hill, Md., bald eagle.

Mulford Biological Exploration of the Amazon Basin, through Dr. William M. Mann, red-faced spider monkey, douroucouli, titi monkey, 2 woolly monkeys, 2 pale capuchins, 2 agoutis, 6 tamarins, toucan, choliba screech owl, guan, penelope, 2 razor-billed curassows, 2 white-backed trumpeters, short-tailed parrot, Maximilian's parrot, mealy parrot, 3 blue-headed parrots, 4 festive parrots, Cassin's macaw, white-eyed paroquet, 4 golden-crowned paroquets, 4 Weddell's paroquets, 7 orange-winged paroquets, 8 golden-winged paroquets, 7 Amazonian caiques, spectacled cayman, and 16 South American turtles.

Mr. C. Bland Payne, Richmond, Va., sparrow hawk.

Miss Dorothy Pickells, Washington, D. C., brown capuchin.

Mr. Marshall Pickett, Brentwood, Md., screech owl.

Mr. Jack Polkinhorn, Washington, D. C., painted turtle.

Mr. J. S. Ritz, Altoona, Pa., two sparrow hawks.

Commander John David Robnett, United States Navy, Washington, D. C., two Santo Domingo parrots.

Mr. Richard J. Scharf, Washington, D. C., two alligators.

Mr. Edward S. Schmid, Washington, D. C., jackdaw, Canadian porcupine, and two Virginia opossums.

Mr. Harry Seamon, Takoma Park, Md., barred owl.

Mrs. Albert Semler, Hagerstown, Md., two American barn owls.

Dr. R. W. Shufeldt, Washington, D. C., glass-snake.

Mr. Robert Stabler, Washington, D. C., black snake.

State Game, Fish and Forest Fire Department, Lansing, Mich., through Hon. John Baird, four coyotes.

Mrs. Anna P. Stewart, Chevy Chase, Md., two canaries.

Mrs. Lucy N. Towson, Washington, D. C., canary.

Mr. J. E. Tyler, Washington, D. C., three moccasins.

Mr. Edward White, Washington, D. C., albino squirrel.

Hon. Arthur H. Wight, Port of Spain, Trinidad, British West Indies, capybara.

Mr. J. Warren Wood, Silver Springs, Md., weasel.

Mrs. Lena D. Woodard, South Washington, Va., barred owl.

Mr. L. T. Zbinden, Washington, D. C., yellow-headed parrot.

Births.—During the year 58 mammals and 28 reptiles were born, and 64 birds were hatched in the park. These records include only such as are reared to a reasonable age, no account being made in these published statistics of young that live only a few days. Mammals born include: Manchurian tiger, 4; dingo, 6; Florida otter, 3; raccoon, 2; gray wolf, 1; hippopotamus, 1; Rocky Mountain sheep, 1; tahr, 1; East African eland, 1; American bison, 1; llama, 1; Indian antelope, 1; Virginia deer, 3; hog deer, 2; Japanese deer, 5; fallow deer, 2; red deer, 5; barasingha, 1; brush-tailed rock wallaby, 2; rufous-bellied wallaby, 3; black-tailed wallaby, 1; great red kangaroo, 5; wallaroo, 1; Trinidad agouti, 2; rhesus monkey, 2; green guenon, 1. Reptiles: Ground rattlesnake, 1; copperhead, 27. Birds hatched were of the following species: Greater snow goose, Canada goose, wood duck, pintail, black duck, mallard, American coot, black-crowned night heron, peafowl, ring-necked pheasant, and European wood pigeon.

The young Manchurian tigers were born August 19, 1921, and at the close of the year were fine, thrifty animals, of good growth. The hippopotamus, born April 27, 1922, is the third young successfully reared in the gardens from the same pair of animals. The success in rearing a young mountain sheep ram last year makes it seem probable that the lamb born this spring will also develop into a perfect animal.

Exchanges.—A number of valuable animals were received in exchange for surplus stock. The accessions include 19 mammals, 166 birds, and 8 reptiles. Special mention should be made of a panda, three yellow-footed rock wallabies, an aard-wolf, and a Hagenbeck's mangabey, none of which have before been on exhibition in the

gardens. The panda is the only Old World representative of the raccoon family and is an animal of striking appearance. It comes from the high Himalaya Mountains of northern India. The aardwolf of South Africa has probably never before been shown alive in America. It is related to the hyenas but is chiefly insectivorous in its habits and lacks the powerful dental equipment of most of the carnivores. Other mammals received in exchange are a lioness, aoudad, great anteater, cape bushbuck, sable antelope, two Malay tapirs, a wombat, brown woolly monkey, anubis baboon, vervet guenon, and two Japanese monkeys.

Among the birds received in exchange special mention should be made of the following species: Hawaiian goose, bean goose, European pochard, tufted duck, European lapwing, greater vasa parrot, and African black vulture.

A regal python, 25 feet long, was received in exchange. This is the largest snake ever exhibited in the park.

Purchases.—A brindled gnu from South Africa, and a young male American elk, were purchased during the year. In addition to these a few small common mammals and birds were purchased at low cost.

Transfers.—An especially fine collection of ostriches, 12 birds in all, were transferred to the park from the United States poultry experiment station, Bureau of Animal Industry, Glendale, Ariz. The lot includes selected representatives of the Somaliland, Nubian, and South African species, and comprises probably the finest show of ostriches in America.

Through the Biological Survey, Department of Agriculture, were received a number of animals collected by field agents of the bureau. These include a badger from Mr. R. E. Bateman, Billings, Mont.; 2 gray wolves from Mr. Charles J. Bayer, Cheyenne, Wyo.; 7 beavers from Mr. Vernon Bailey, chief field naturalist; a wood duck and a cardinal from Mr. George A. Lawyer, chief game warden; a desert tortoise from Mr. M. E. Musgrave, Phoenix, Ariz.; and 12 Florida gopher tortoises from the survey laboratories.

The Bureau of Fisheries, Department of Commerce, contributed 5 specimens of the snapping turtle.

REMOVALS.

Surplus animals to the number of 44 were sent away during the year in exchange for other stock. Among these were the following mammals that had been born and reared in the park: Indian water buffalo, 1; American bison, 1; Rocky Mountain sheep, 1; Indian antelope, 1; llama, 2; guanaco, 1; red deer, 7; Japanese deer, 3;

barasingha, 1; dingo, 2; gray wolf, 1; European brown bear, 4; red kangaroo, 2; and rufous-bellied wallaby, 2.

A number of animals on deposit were returned to owners.

While the death rate has been kept low for the collection as a whole, there have been some serious losses of animals long in the park. The records of some of these, interesting because of longevity in captivity, are as follows: A black vulture (*Coragyps urubu*) received as a bird of the year November 26, 1900, was killed by its cage mate, a bird of the same species, December 28, 1921, 21 years, 1 month, and 2 days after arrival. A female South American tapir, received from Demerara August 28, 1901, then about 4 years of age, died September 7, 1921, after 20 years and 10 days of life in the National Zoological Park. Nine young were born to this animal during this period, seven of which were reared. The immediate cause of death was tuberculosis. A male gray wolf (*Canis nubilus*), born in the park March 29, 1905, died at an age of 16 years, 3 months, and 5 days, on July 4, 1921. A male llama, born in the park April 28, 1907, died of pyemia at an age of 14 years, 10 months, and 7 days, on March 7, 1922. A female California sea lion received May 25, 1907, died 14 years, 2 months, and 5 days after arrival on July 30, 1921. A cariama (*Cariama cristata*) received from Dr. Clemente Onelli, director of the Municipal Zoological Gardens, Buenos Aires, March 14, 1908, died 13 years, 4 months, and 1 day later, on July 15, 1921. A grizzly bear, male, received from the Yellowstone National Park July 29, 1908, died March 27, 1922. This bear was about 3½ years old on arrival, lived in the park 13 years, 7 months, and 28 days, and its death was clearly due to advanced age. The female harbor seal (*Phoca vitulina*), received January 19, 1910, died of enteritis on March 9, 1922, after 12 years, 1 month, and 18 days of life in the park. A female wart hog, presented by Mr. W. N. McMillan, which reached the park December 19, 1909, died July 29, 1921, 11 years, 7 months, and 10 days after arrival. A female kinkajou (*Potos flavus*), received from Panama June 17, 1910, died after 11 years, 1 month, and 5 days of life in the park, on July 22, 1921. A female Woodhouse's wolf (*Canis frustror*), born in the park April 17, 1911, died January 7, 1922, at an age of 10 years, 8 months, and 21 days. A female gray coatimundi (*Nasua narica*) received April 2, 1913, died February 22, 1922, after 8 years, 10 months, and 20 days in the park. The European badger (*Meles meles*) received from the London Zoological Gardens May 1, 1915, died 6 years, 6 months, and 11 days later, on November 12, 1921.

Other serious losses include the Florida manatee from septic peritonitis, July 16, 1921; Mongolian wild horse (*Equus przewal-*

skii) from inflammation of bladder, November 27, 1921; an Arabian camel, hemorrhagic cystitis, April 3, 1922; a female Rocky Mountain sheep from metroperitonitis, June 6, 1922; two Count Raggi's birds of paradise, enteritis, February 7 and 9, 1922; and the last trumpeter swan, the property of Mr. R. M. Barnes, Lacon, Ill., which had been on deposit since April 15, 1917. The swan died of tuberculosis of the liver on June 14, 1922.

Post-mortem examinations were made, in most cases, by the pathological division of the Bureau of Animal Industry. Two examinations were made by Dr. Adolph H. Schultz, of the Carnegie Institution, Laboratory of Embryology, and one by Dr. C. W. Stiles at the Hygienic Laboratory, Bureau of Public Health Service. The following list shows the results of autopsies, the cases being arranged by groups:

CAUSES OF DEATH.

MAMMALS.

Marsupialia: Congestion of lungs, 1; pleurisy and pneumonia, 1; enteritis, 2; septicemia, 1; accident, 1; old age, 1.

Carnivora: Pneumonia, 1; tuberculosis, 2; enteritis, 1; gastroenteritis, 3; old age, 1; no cause found, 1.

Rodentia: Tuberculosis, 1; septic pleuropneumonia, 1; enteritis, 2.

Primates: Bronchopneumonia, 1; tuberculosis, 1; enteritis, 1; gastroenteritis, 1; colitis, 2; parasitic peritonitis, 2.

Artiodactyla: Pneumonia, 1; verminous bronchopneumonia, 2; pleurisy, 1; tuberculosis, 1; enteritis, 1; metroperitonitis, 1; hemorrhagic cystitis, 1; pyemia, 1; anemia, 1; accident, 1; no cause found, 1.

Perissodactyla: Tuberculosis, 1; prolapse of rectum, 1.

Sirenia: Peritonitis, 1.

BIRDS.

Ratitæ: Pleurisy and peritonitis, 1.

Ciconiiformes: Aspergillosis, 1; enteritis, 1; anemia, 3; no cause found, 5.

Anseriformes: Tuberculosis, 6; aspergillosis, 1; enteritis, 1; abscess of intestine, 1; no cause found, 4.

Falconiformes: Anemia, 1; no cause found, 1.

Galliformes: Enteritis, 4; anemia, 1.

Gruiformes: No cause found, 1.

Charadriiformes: Pneumonia, 2; aspergillosis, 1; no cause found, 2.

Coraciiformes: No cause found, 1.

Passeriformes: Aspergillosis, 1; enteritis, 4; abscess of lung, 1.

REPTILES.

Serpentes: No cause found, 1.

A total of 68 specimens—26 mammals, 25 birds, and 17 reptiles—of special scientific importance, were transferred after death to the United States National Museum. Four dead mammals were de-

livered for scientific investigations to the Carnegie Laboratory of Embryology, Johns Hopkins Medical School, Baltimore; two to the American Museum of Natural History, New York City; and one to the Hygienic Laboratory, Public Health Service, Washington, D. C. Four skins of birds were added to the reference collection of "dealers' cage birds" in the office of the National Zoological Park.

ANIMALS IN THE COLLECTION JUNE 30, 1922.

MAMMALS.

MARSUPIALIA.

Virginia opossum (*Didelphis virginiana*)	4
Tasmanian devil (*Sarcophilus harrisii*)	1
Australian opossum (*Trichosurus vulpecula*)	2
Flying phalanger (*Petaurus breviceps*)	8
Brush-tailed rock wallaby (*Petrogale penicillata*)	3
Yellow-footed rock wallaby (*Petrogale xanthopus*)	3
Rufous-bellied wallaby (*Macropus billardierii*)	7
Black-tailed wallaby (*Macropus bicolor*)	3
Black-faced kangaroo (*Macropus melanops*)	2
Wallaroo (*Macropus robustus*)	2
Red kangaroo (*Macropus rufus*)	11
Wombat (*Phascolomys mitchelli*)	1

CARNIVORA.

Kadiak bear (*Ursus middendorffi*)	2
Alaska Peninsula bear (*Ursus gyas*)	2
Yakutat bear (*Ursus dalli*)	1
Kidder's bear (*Ursus kidderi*)	2
European bear (*Ursus arctos*)	2
Grizzly bear (*Ursus horribilis*)	1
Apache grizzly (*Ursus apache*)	1
Himalayan bear (*Ursus thibetanus*)	1
Black bear (*Ursus americanus*)	1
Cinnamon bear (*Ursus americanus cinnamomum*)	2
Florida bear (*Ursus floridanus*)	1
Glacier bear (*Ursus emmonsii*)	1
Sun bear (*Helarctos malayanus*)	1
Sloth bear (*Melursus ursinus*)	1
Polar bear (*Thalarctos maritimus*)	2
Dingo (*Canis dingo*)	3
Eskimo dog (*Canis familiaris*)	2
Gray wolf (*Canis nubilus*)	9
Southern wolf (*Canis floridanus*)	1
Woodhouse's wolf (*Canis frustror*)	1
Texas red wolf (*Canis rufus*)	1

CARNIVORA—continued.

Coyote (*Canis latrans*)	4
Plains coyote (*Canis nebracensis*)	1
Red fox (*Vulpes fulva*)	6
Great-eared fox (*Otocyon megalotis*)	1
Gray fox (*Urocyon cinereoargenteus*)	4
Cacomistle (*Bassariscus astutus*)	1
Panda (*Ailurus fulgens*)	1
Raccoon (*Procyon lotor*)	18
Gray coatimundi (*Nasua narica*)	1
Kinkajou (*Potos flavus*)	2
Mexican kinkajou (*Potos flavus azteeus*)	1
Weasel (*Mustela noveboracensis*)	1
Tayra (*Tayra barbara*)	1
Skunk (*Mephitis nigra*)	2
Florida otter (*Lutra canadensis vaga*)	3
Palm civet (*Paradoxurus hermaphroditus*)	2
Wahlberg's mongoose (*Helogale parvula*)	1
Aard-wolf (*Proteles cristatus*)	1
Spotted hyena (*Crocuta crocuta*)	1
Striped hyena (*Hyæna hyæna*)	1
African cheetah (*Acinonyx jubatus*)	2
Lion (*Felis leo*)	3
Bengal tiger (*Felis tigris*)	1
Manchurian tiger (*Felis tigris longipilis*)	6
Leopard (*Felis pardus*)	1
East African leopard (*Felis pardus suahelica*)	1
Jaguar (*Felis onca*)	1
Brazilian ocelot (*Felis pardalis brasiliensis*)	1
Snow leopard (*Felis uncia*)	1
Mexican puma (*Felis azteca*)	2
Mountain lion (*Felis hippolestes*)	3
Canada lynx (*Lynx canadensis*)	1
Northern wild cat (*Lynx uinta*)	3
Bay lynx (*Lynx rufus*)	2

PINNIPEDIA.

California sea-lion (*Zalophus californianus*)	1

ANIMALS IN THE COLLECTION JUNE 30, 1922—Continued.

MAMMALS—continued.

RODENTIA.

Woodchuck (*Marmota monax*)	2
Dusky marmot (*Marmota flaviventris obscura*)	1
Prairie-dog (*Cynomys ludovicianus*)	5
White-tailed prairie dog (*Cynomys gunnisoni*)	1
Antelope squirrel (*Ammospermophilus leucurus*)	1
Arizona antelope squirrel (*Ammospermophilus harrisii*)	1
Chipmunk (*Eutamias neglectus*)	3
Albino squirrel (*Sciurus carolinensis*)	3
Baird's pocket mouse (*Perognathus flavus*)	1
Bailey's pocket mouse (*Perognathus baileyi*)	2
Jumping mouse (*Zapus hudsonius*)	1
Montana white-footed mouse (*Peromyscus leucopus aridulus*)	1
Nebraska white-footed mouse (*Peromyscus maniculatus osgoodi*)	2
African porcupine (*Hystrix africæaustralis*)	1
Malay porcupine (*Acanthion brachyurum*)	2
Coypu (*Myocastor coypus*)	3
Central American paca (*Cuniculus paca virgatus*)	1
Mexican agouti (*Dasyprocta mexicana*)	1
Sooty agouti (*Dasyprocta fuliginosa*)	1
Speckled agouti (*Dasyprocta punctata*)	2
Panama agouti (*Dasyprocta punctata isthmica*)	1
Azara's agouti (*Dasyprocta azaræ*)	2
Trinidad agouti (*Dasyprocta rubrata*)	4
Crested agouti (*Dasyprocta cristata*)	2
Yellow-rumped agouti (*Dasyprocta lucifer cayennæ*)	1
Peruvian guinea pig (*Cavia tschudii pallidor*)	1
Guinea pig (*Cavia porcellus*)	8
Capybara (*Hydrochærus hydrochæris*)	1

LAGOMORPHA.

Domestic rabbit (*Oryctolagus cuniculus*)	18

EDENTATA.

Great anteater (*Myrmecophaga tridactyla*)	1

PRIMATES.

Red-faced spider monkey (*Ateles paniscus*)	1
Feline douroucouli (*Aotus infulatus*)	1
Brown woolly monkey (*Lagothrix infumata*)	1
Black-headed woolly monkey (*Lagothrix ubericola*)	1

PRIMATES—continued.

White-throated capuchin (*Cebus capucinus*)	4
Pale capuchin (*Cebus unicolor*)	2
Brown capuchin (*Cebus fatuellus*)	3
Azara's capuchin (*Cebus azaræ*)	1
Titi monkey (*Saimiri sciureus*)	1
Negro tamarin (*Cercopithecus ursulus*)	1
Chacma (*Papio porcarius*)	1
Anubis baboon (*Papio cynocephalus*)	1
Hamadryas baboon (*Papio hamadryas*)	1
East African baboon (*Papio ibeanus*)	1
Mandrill (*Papio sphinx*)	1
Drill (*Papio leucophæus*)	1
Moor macaque (*Cynopithecus maurus*)	1
Barbary ape (*Simia sylvanus*)	2
Brown macaque (*Macaca speciosa*)	1
Japanese macaque (*Macaca fuscata*)	2
Pig-tailed monkey (*Macaca nemestrina*)	1
Burmese macaque (*Macaca andamanensis*)	1
Rhesus monkey (*Macaca rhesus*)	28
Bonnet monkey (*Macaca sinica*)	1
Crab-eating macaque (*Macaca irus*)	1
Javan macaque (*Macaca mordax*)	4
Black mangabey (*Cercocebus aterrimus*)	1
Sooty mangabey (*Cercocebus fuliginosus*)	2
Hagenbeck's mangabey (*Cercocebus hagenbecki*)	1
White-collared mangabey (*Cercocebus torquatus*)	1
Green guenon (*Lasiopyga callitrichus*)	3
Vervet guenon (*Lasiopyga pygerythra*)	2
Mona (*Lasiopyga mona*)	4
Roloway guenon (*Lasiopyga roloway*)	1
Patas monkey (*Erythrocebus patas*)	1
Chimpanzee (*Pan satyrus*)	1
Orang-utan (*Pongo pygmæus*)	1

ARTIODACTYLA.

Wild boar (*Sus scrofa*)	1
Wart-hog (*Phacochœrus æthiopicus*)	1
Collared peccary (*Pecari angulatus*)	1
Hippopotamus (*Hippopotamus amphibius*)	3
Bactrian camel (*Camelus bactrianus*)	2
Arabian camel (*Camelus dromedarius*)	1
Guanaco (*Lama guanicoe*)	3
Llama (*Lama glama*)	5
Alpaca (*Lama pacos*)	1
Fallow deer (*Dama dama*)	7
Axis deer (*Axis axis*)	3
Hog deer (*Hyelaphus porcinus*)	8
Sambar (*Rusa unicolor*)	2
Barasingha (*Rucervus duvaucelii*)	9
Burmese deer (*Rucervus eldii*)	1
Japanese deer (*Sika nippon*)	13
Red deer (*Cervus elaphus*)	18

ANIMALS IN THE COLLECTION JUNE 30, 1922—Continued.

MAMMALS—continued.

ARTIODACTYLA—continued.

Kashmir deer (*Cervus hanglu*)	2
Bedford deer (*Cervus xanthopygus*)	6
American elk (*Cervus canadensis*)	5
Virginia deer (*Odocoilcus virginianus*)	10
Panama deer (*Odocoileus chiriquensis*)	1
Mule deer (*Odocoileus hemionus*)	2
Black-tailed deer (*Odocoileus columbianus*)	1
Trinidad brocket (*Mazama simplicicornis*)	1
Blesbok (*Damaliscus albifrons*)	2
White-tailed gnu (*Connochætes gnou*)	1
Brindled gnu (*Connochætes taurinus*)	1
Lechwe (*Onotragus leche*)	1
Sable antelope (*Egocerus niger*)	1
Indian antelope (*Antilope cervicapra*)	4
Nilgai (*Boselaphus tragocamelus*)	2
East African eland (*Taurotragus oryx livingstonii*)	3
Cape bushbuck (*Tragelaphus sylvaticus*)	1
Tahr (*Hemitragus jemlahicus*)	4
Mountain goat (*Oreamnos americanus*)	3
Aoudad (*Ammotragus lervia*)	2

ARTIODACTYLA—continued.

Rocky Mountain sheep (*Ovis canadensis*)	5
Arizona mountain sheep (*Ovis canadensis gaillardi*)	1
Barbados sheep (*Ovis aries*)	2
Zebu (*Bos indicus*)	1
Yak (*Poëphagus grunniens*)	5
American bison (*Bison bison*)	13
Indian buffalo (*Bubalus bubalis*)	2

PERISSODACTYLA.

Malay tapir (*Tapirus indicus*)	1
Brazilian tapir (*Tapirus terrestris*)	1
Grant's zebra (*Equus quagga granti*)	1
Grevy's zebra (*Equus grevyi*)	1
Zebra-horse hybrid (*Equus grevyi-caballus*)	1
Zebra-ass hybrid (*Equus grevyi-asinus*)	1

PROBOSCIDEA.

Abyssinian elephant (*Loxodonta africana oxyotis*)	1
Sumatran elephant (*Elephas sumatranus*)	2

BIRDS.

RATITÆ.

South African ostrich (*Struthio australis*)	6
Somaliland ostrich (*Struthio molybdophanes*)	2
Nubian ostrich (*Struthio camelus*)	5
Rhea (*Rhea americana*)	2
Sclater's cassowary (*Casuarius philipi*)	1
Emu (*Dromœus novæhollandiæ*)	2

CICONIIFORMES.

American white pelican (*Pelecanus erythrorhynchos*)	7
European white pelican (*Pelecanus onocrotalus*)	2
Roseate pelican (*Pelecanus roseus*)	2
Australian pelican (*Pelecanus conspicillatus*)	2
Brown pelican (*Pelecanus occidentalis*)	10
Florida cormorant (*Phalacrocorax auritus floridanus*)	5
Great white heron (*Ardea occidentalis*)	2
Goliath heron (*Ardea goliath*)	1
American egret (*Casmerodius egretta*)	3
Snowy egret (*Egretta candidissima*)	3
Black-crowned night heron (*Nycticorax nycticorax nævius*)	33
Boatbill (*Cochlearius cochlearius*)	2
White stork (*Ciconia ciconia*)	2
Black stork (*Ciconia nigra*)	1
Indian jabiru (*Xenorhynchus asiaticus*)	1

CICONIIFORMES—continued.

Straw-necked ibis (*Carphibis spinicollis*)	1
Sacred ibis (*Threskiornis æthiopicus*)	3
Australian ibis (*Threskiornis strictipennis*)	2
White ibis (*Guara alba*)	12
Scarlet ibis (*Guara rubra*)	4
Roseate spoonbill (*Ajaia ajaja*)	2
European flamingo (*Phœnicopterus roseus*)	1

ANSERIFORMES.

Mallard (*Anas platyrhynchos*)	15
Black duck (*Anas rubripes*)	34
Australian black duck (*Anas superciliosa*)	2
Gadwall (*Chaulelasmus streperus*)	3
European widgeon (*Mareca penelope*)	7
Baldpate (*Mareca americana*)	6
Green-winged teal (*Nettion carolinense*)	15
European teal (*Nettion crecca*)	10
Baikal teal (*Nettion formosum*)	6
Blue-winged teal (*Querquedula discors*)	9
Garganey (*Querquedula querquedula*)	6
Cinnamon teal (*Querquedula cyanoptera*)	1
Shoveler (*Spatula clypeata*)	4
Pintail (*Dafila acuta*)	12
Wood duck (*Aix sponsa*)	13
Mandarin duck (*Dendronessa galericulata*)	14
Canvasback (*Marila vallisineria*)	4

ANIMALS IN THE COLLECTION JUNE 30, 1922--Continued.

BIRDS—continued.

ANSERIFORMES—continued.

European pochard (*Marila ferina*)	4
Redhead (*Marila americana*)	9
Ring-necked duck (*Marila collaris*)	1
Tufted duck (*Marila fuligula*)	4
Lesser scaup duck (*Marila affinis*)	5
Greater scaup duck (*Marila marila*)	11
White-eyed duck (*Marila nyroca*)	1
Rosy-billed pochard (*Metopiana peposaca*)	4
Egyptian goose (*Chenalopex ægyptiacus*)	4
Upland goose (*Chloëphaga leucoptera*)	1
Hawaiian goose (*Nesochen sandvicensis*)	2
Snow goose (*Chen hyperboreus*)	2
Greater snow goose (*Chen hyperboreus nivalis*)	7
Blue goose (*Chen cærulescens*)	7
White-fronted goose (*Anser albifrons*)	4
American white-fronted goose (*Anser albifrons gambeli*)	3
Bean goose (*Anser fabalis*)	2
Bar-headed goose (*Eulabeia indica*)	3
Canada goose (*Branta canadensis*)	10
Hutchins's goose (*Branta canadensis hutchinsii*)	8
Cackling goose (*Branta canadensis minima*)	2
Brant (*Branta bernicla glaucogastra*)	13
Barnacle goose (*Branta leucopsis*)	7
Spur-winged goose (*Plectropterus gambensis*)	2
Pied goose (*Anseranas semipalmata*)	2
Black-bellied tree duck (*Dendrocygna autumnalis*)	6
Eyton's tree duck (*Dendrocygna eytoni*)	4
White-faced tree duck (*Dendrocygna viduata*)	2
Mute swan (*Cygnus gibbus*)	2
Whistling swan (*Olor columbianus*)	1
Black swan (*Chenopis atrata*)	2

FALCONIFORMES.

South American condor (*Vultur gryphus*)	1
California condor (*Gymnogyps californianus*)	3
Turkey vulture (*Cathartes aura*)	3
Black vulture (*Coragyps urubu*)	1
King vulture (*Sarcoramphus papa*)	2
Secretary bird (*Sagittarius serpentarius*)	1
Griffon vulture (*Gyps fulvus*)	1
African black vulture (*Torgos tracheliotus*)	1
Cinereous vulture (*Aegypius monachus*)	2
Caracara (*Polyborus cheriway*)	2
Wedge-tailed eagle (*Uroaëtus audax*)	2
Golden eagle (*Aquila chrysaëtos*)	4
White-bellied sea eagle (*Cuncuma leucogaster*)	2

FALCONIFORMES—continued.

Bald eagle (*Haliæetus leucocephalus*)	13
Alaskan bald eagle (*Haliæetus leucocephalus alascanus*)	3
Broad-winged hawk (*Buteo platypterus*)	1
Red-tailed hawk (*Buteo borealis*)	5
Sparrow hawk (*Falco sparverius*)	7

GALLIFORMES.

Razor-billed curassow (*Mitu mitu*)	2
Penelope (*Penelope boliviana*)	1
Guan (*Ortalis albiventris*)	1
Chachalaca (*Ortalis vetula*)	1
Peafowl (*Pavo cristatus*)	34
Peacock pheasant (*Polyplectron bicalcaratum*)	1
Silver pheasant (*Gennæus nycthemerus*)	1
Ring-necked pheasant (*Phasianus torquatus*)	12
Bobwhite (*Colinus virginianus*)	1
Gambel's quail (*Lophortyx gambelli*)	2
Valley quail (*Lophortyx californica vallicola*)	1
Scaled quail (*Callipepla squamata*)	1

GRUIFORMES.

East Indian gallinule (*Porphyrio calvus*)	5
American coot (*Fulica americana*)	5
South Island weka rail (*Ocydromus australis*)	3
Short-winged weka (*Ocydromus brachypterus*)	2
Earl's weka (*Ocydromus earli*)	1
Whooping crane (*Grus americana*)	1
Sandhill crane (*Grus mexicana*)	2
Little brown crane (*Grus canadensis*)	6
White-necked crane (*Grus leucauchen*)	1
Indian white crane (*Grus leucogeranus*)	1
Lilford's crane (*Grus lilfordi*)	2
Sarus crane (*Grus collaris*)	1
Australian crane (*Grus rubicunda*)	2
Demoiselle crane (*Anthropoides virgo*)	4
Crowned crane (*Balearica pavonina*)	1
White-backed trumpeter (*Psophia leucoptera*)	3
Kagu (*Rhynochetos jubatus*)	1

CHARADRIIFORMES.

Lapwing (*Vanellus vanellus*)	3
Yellow-wattled lapwing (*Lobivanellus indicus*)	1
Pacific gull (*Gabianus pacificus*)	2
Great black-backed gull (*Larus marinus*)	1
Herring gull (*Larus argentatus*)	3
Laughing gull (*Larus atricilla*)	2
Australian crested pigeon (*Ocyphaps lophotes*)	5
Bronze-wing pigeon (*Phaps chalcoptera*)	3

ANIMALS IN THE COLLECTION JUNE 30, 1922—Continued.

BIRDS—continued.

CHARADRIIFORMES—continued.

Wonga-wonga pigeon (*Leucosarcia picata*)	4
Wood pigeon (*Columba palumbus*)	9
Mourning dove (*Zenaidura macroura*)	2
Necklaced dove (*Spilopelia tigrina*)	4
Zebra dove (*Geopelia striata*)	3
Bar-shouldered dove (*Geopelia humeralis*)	2
Inca dove (*Scardafella inca*)	2
Cuban ground dove (*Chæmepelia passerina aflavida*)	1
Green-winged dove (*Chalcophaps indica*)	2
New Guinea green dove (*Chalcophaps chrysochlora*)	5
Ringed turtle-dove (*Streptopelia risoria*)	1

PSITTACIFORMES.

Kea (*Nestor notabilis*)	4
Cockateel (*Calopsitta novæhollandiæ*)	1
Roseate cockatoo (*Kakatoe roseicapilla*)	17
Bare-eyed cockatoo (*Kakatoe gymnopis*)	3
Leadbeater's cockatoo (*Kakatoe leadbeateri*)	4
White cockatoo (*Kakatoe alba*)	2
Sulphur-crested cockatoo (*Kakatoe galerita*)	8
Great red-crested cockatoo (*Kakatoe moluccensis*)	1
Cassin's macaw (*Ara auricollis*)	1
Mexican green macaw (*Ara mexicana*)	2
Blue-and-yellow macaw (*Ara ararauna*)	2
Red-and-blue-and-yellow macaw (*Ara macao*)	8
Hahn's macaw (*Diopsittaca hahni*)	1
White-eyed paroquet (*Aratinga leucophthalmus*)	1
Golden-crowned paroquet (*Eupsittula aurea*)	3
Weddell's paroquet (*Eupsittula weddellii*)	4
Blue-winged parrotlet (*Psittacula passerina*)	11
Yellow-winged paroquet (*Tirica virescens*)	1
Tui paroquet (*Brotogeris stthomæ*)	2
Golden paroquet (*Brotogeris chrysosema*)	8
Tovi paroquet (*Brotogeris jugularis*)	4
Orange-winged paroquet (*Brotogeris chiriri*)	6
Yellow-naped parrot (*Amazona auropalliata*)	3
Yellow-cheeked parrot (*Amazona autumnalis*)	1
Mealy parrot (*Amazona farinosa*)	1
Orange-winged parrot (*Amazona amazonica*)	4

PSITTTACIFORMES—continued.

Blue-fronted parrot (*Amazona æstiva*)	1
Red-crowned parrot (*Amazona viridigenalis*)	6
Double yellow-head parrot (*Amazona oratrix*)	7
Yellow-headed parrot (*Amazona ochrocephala*)	5
Festive parrot (*Amazona festiva*)	6
Santo Domingo parrot (*Amazona ventralis*)	2
Cuban parrot (*Amazona leucocephala*)	1
Maximilian's parrot (*Pionus maximiliani*)	1
Blue-headed parrot (*Pionus menstruus*)	3
Amazonian caique (*Pionites xanthomeria*)	7
Short-tailed parrot (*Graydidascalus brachyurus*)	1
Lesser vasa parrot (*Coracopsis nigra*)	1
Greater vasa parrot (*Coracopsis vasa*)	1
Pennant's paroquet (*Platycercus elegans*)	1
Rosella paroquet (*Platycercus eximius*)	1
Black-tailed paroquet (*Polytelis melanura*)	2
King paroquet (*Aprosmictus cyanopygius*)	3
Ring-necked paroquet (*Conurus torquatus*)	1
Nepalese paroquet (*Conurus nepalensis*)	1
Grass paroquet (*Melopsittacus undulatus*)	61

CORACIIFORMES.

Giant kingfisher (*Dacelo gigas*)	2
Yellow-billed hornbill (*Lophoceros leucomelas*)	2
Barred owl (*Strix varia*)	7
Snowy owl (*Nyctea nyctea*)	1
Screech owl (*Otus asio*)	3
Choliba screech owl (*Otus choliba*)	1
Great horned owl (*Bubo virginianus*)	13
American barn owl (*Tyto perlata pratincola*)	7
Ariel toucan (*Ramphastos ariel*)	1

PASSERIFORMES.

Cock of the rock (*Rupicola rupicola*)	1
Silver-eared hill-tit (*Mesia argentauris*)	3
Red-billed hill-tit (*Liothrix luteus*)	8
Black-gorgeted laughing-thrush (*Garrulax pectoralis*)	2
White-eared bulbul (*Otocompsa leucotis*)	3
European blackbird (*Turdus merula*)	2
Piping crow-shrike (*Gymnorhina tibicen*)	4
Satin bower-bird (*Ptilonorhynchus violaceus*)	1
European raven (*Corvus corax*)	1

ANIMALS IN THE COLLECTION JUNE 30, 1922—Continued.

BIRDS—continued.

PASSERIFORMES—continued.

Australian crow (*Corvus coronoides*)	1
Jackdaw (*Corvus monedula*)	1
Yucatan jay (*Cissilopha yucatanica*)	1
Blue jay (*Cyanocitta cristata*)	3
Green jay (*Xanthoura luxuosa*)	1
Australian gray jumper (*Struthidea cinerea*)	1
Starling (*Sturnus vulgaris*)	9
Crimson tanager (*Ramphocelus dimidiatus*)	1
Blue tanager (*Thraupis cana*)	2
Pin-tailed whydah (*Vidua principalis*)	1
Paradise whydah (*Steganura paradisea*)	3
Shaft-tailed whydah (*Tetrænura regia*)	2
Napolean weaver (*Pyromelana afra*)	1
Red-billed weaver (*Quelea quelea*)	1
Madagascar weaver (*Foudia madagascariensis*)	3
Fire finch (*Lagonosticta senegala*)	2
Strawberry finch (*Amandava amandava*)	6
Cordon bleu (*Estrilda phœnicotis*)	1
Nutmeg finch (*Munia punctulata*)	6
White-headed nun (*Munia maja*)	4
Black-headed nun (*Munia atricapilla*)	2
Java finch (*Munia oryzivora*)	4
White Java finch (*Munia oryzivora*)	3
Fawn-and-white bengalee (*Urolonchа flavomaculata*)	3
Brown-and-white bengalee (*Urolonchа griseomaculata*)	1
Masked grassfinch (*Poëphila personata*)	9
Black-faced Gouldian finch (*Poëphila gouldiæ*)	8
Red-faced Gouldian finch (*Poëphila mirabilis*)	8

PASSERIFORMES—continued.

Diamond finch (*Steganopleura guttata*)	6
Zebra finch (*Tæniopygia castanotis*)	5
Cut-throat finch (*Amadina fasciata*)	3
Vera Cruz red-wing (*Agelaius phœniceus richmondi*)	1
Purple grackle (*Quiscalus quiscula*)	4
Yellow-backed cacique (*Cacicus cela*)	1
Bullfinch (*Pyrrhula pyrrhula*)	7
Greenfinch (*Chloris chloris*)	3
Yellowhammer (*Emberiza citrinella*)	1
European goldfinch (*Carduelis carduelis*)	7
Bramblefinch (*Fringilla montifringilla*)	6
European siskin (*Spinus spinus*)	1
Mexican goldfinch (*Astragalinus psaltria mexicanus*)	1
House finch (*Carpodacus mexicanus frontalis*)	2
Purple finch (*Carpodacus purpureus*)	1
Canary (*Serinus canarius*)	9
Green singing finch (*Serinus icterus*)	1
Slate-colored junco (*Junco hyemalis*)	2
Tree sparrow (*Spizella monticola*)	1
White-throated sparrow (*Zonotrichia albicollis*)	4
Song sparrow (*Melospiza melodia*)	1
San Diego song sparrow (*Melospiza melodia cooperi*)	3
Fox sparrow (*Passerella iliaca*)	1
California towhee (*Pipilo crissalis*)	2
Saffron finch (*Sicalis flaveola*)	1
Seed-eater (*Sporophila gutturalis*)	2
Nonpareil (*Passerina ciris*)	5
Blue grosbeak (*Guiraca cærulea*)	1

REPTILES.

Spectacled cayman (*Caiman sclerops*)	1
Alligator (*Alligator mississipiensis*)	41
Gila monster (*Heloderma suspectum*)	6
Giant zonure (*Zonurus giganteus*)	6
Rock python (*Python molurus*)	2
Regal python (*Python reticulatus*)	1
Anaconda (*Eunectes murinus*)	2
Boa constrictor (*Constrictor constrictor*)	3
Blacksnake (*Coluber constrictor*)	2
Chicken snake (*Elaphe quadrivittata*)	1
Gopher snake (*Drymarchon corais couperi*)	1
Garter snake (*Thamnophis sirtalis*)	2
Moccasin (*Agkistrodon piscivorus*)	3
Copperhead (*Agkistrodon mokasen*)	1
Western diamond rattler (*Crotalus atrox*)	1
Banded rattlesnake (*Crotalus horridus*)	1
Ground rattler (*Sistrurus miliarius*)	1
Snapping turtle (*Chelydra serpentina*)	6
Rossignon's snapping turtle (*Chelydra rossignonii*)	1

Wood turtle (*Clemmys insculpta*)	1
Amazon terrapin (*Podocnemis expansa*)	1
South American mud turtle (*Kinasternon scorpioides*)	6
South American terrapin (*Nicoria punctularia*)	1
Painted turtle (*Chrysemys picta*)	2
Cooter (*Pseudemys scripta*)	1
Central American cooter (*Pseudemys ornata*)	1
Box-tortoise (*Terrapene carolina*)	1
Gopher tortoise (*Gopherus polyphemus*)	13
Desert tortoise (*Gopherus agassizii*)	1
Duncan Island tortoise (*Testudo ephippium*)	1
Indefatigable Island tortoise (*Testudo porteri*)	1
Albemarle Island tortoise (*Testudo vicina*)	2
South American tortoise (*Testudo denticulata*)	8

STATEMENT OF THE COLLECTION.

Accessions during the year.

	Mammals.	Birds.	Reptiles.	Total.
Presented	46	131	40	217
Born and hatched in National Zoological Park	58	64	28	150
Received in exchange	19	166	8	193
Purchased	5	39		44
Transferred from other Government departments	10	14	18	42
Captured	1			1
Deposited	3	5	1	9
Total	142	419	95	656

SUMMARY.

Animals on hand July 1, 1921	1,545
Accessions during the year	656
Total animals handled	2,201
Deduct loss (by exchange, death, and return of animals on deposit)	520
Animals on hand June 30, 1922	1,681

Class.	Species.	Individuals.
Mammals	187	490
Birds	262	1,069
Reptiles	33	122
Total June 30, 1922	482	1,681

The collection is now larger than ever before. The number of species on exhibition on June 30 is 4 more, and the total number of animals is 130 more than in any previous year.

VISITORS.

The total number of visitors to the park, for the fiscal year, as determined by count and estimate, was 2,164,254. This is the third year that the attendance has exceeded 2,000,000. The greatest attendance in any one month was 394,703 in April, 1922, an average per day of 13,156.

The attendance by months was as follows:

1921.		1922.	
July	167,650	January	51,676
August	172,500	February	77,541
September	197,700	March	181,039
October	258,000	April	394,703
November	123,325	May	278,550
December	79,570	June	180,000

Schools, classes, and other organizations visiting the park during the year numbered 205, with a total of 13,585 individuals.

IMPROVEMENTS.

The work of grading in the west central part of the park, commenced six years ago but discontinued during the war, was again taken up and the major part of the leveling and filling, as originally planned, was completed during the year. A large area of ground is now available for comparatively level paddocks for the exhibition of hoofed animals, and the way is opened up for decided improvements in the main roadway traversing the park. Many trees removed during this work were cut into logs and, during the winter, sawed into lumber of suitable grades for regular use.

The entire western wall of the antelope house, involving the cages and yards, long in a bad state of repair, was entirely rebuilt. The lower part was extended out, with concrete walls and new roof. The platform and approach to the eastern entrance were also remodeled. The building has been greatly improved in appearance and the animals have been given much more satisfactory quarters.

The older bear dens near the Harvard Street entrance were thoroughly repaired, provided with new concrete floor, tank, and gutter, and the ironwork painted.

Three large outdoor cages for hawks, owls, and Australian grass paroquets were constructed; the Henderson outdoor parrot cage was covered with new wire and painted; the inside quarters for hippopotamuses and tapirs repaired and enlarged; a concrete storehouse for paints and oils was built near the machine shop; the tennis courts were improved; repairs were made to the heating service in the monkey and lion houses; an electric pump and motor was installed at the pelican pond so that water from the creek can be used; and the gap in the boundary fence along the southern border of the park was closed by a new wire fence.

At the close of the year considerable progress had been made in a complete rebuilding of the old wolf yards and fox dens below the sea-lion pool.

ALTERATIONS OF BOUNDARIES.

There is available for the purchase of a narrow strip of land near the Adams Mill Road entrance, between the present park boundary and Adams Mill Road, $4,903.66. On March 24, 1921, the attention of the Secretary of the Treasury was called to the provisions of the sundry civil act relating to the purchase of this land. The matter was referred to the United States attorney's office, and, the owners having declined to sell within the limits set by the act for purchase by agreement, steps were taken toward the institution of proceedings of condemnation. During the past year no further progress has been reported.

IMPORTANT NEEDS.

Restaurant.—A suitable restaurant building remains the most urgent need of the park. As pointed out in previous reports the old refreshment stand, originally constructed when the attendance was very small, is in a bad condition and is wholly inadequate to serve the needs of the public. Following the acquisition by the park of a large quantity of valuable chestnut and oak timbers and lumber, as mentioned in the report for last year, and in consideration of the fact that much of the work of construction can now be done by regular park employees, the estimated necessary appropriation for such a structure as is needed has been reduced to $20,000. The old refreshment stand at the Connecticut Avenue entrance, on land recently transferred to the Government as an addition to the park, should also be replaced by a new and more sightly booth. The increased income from rental of these two concessions will well repay for the construction of buildings adequate for the service of the constantly increasing number of visitors.

Bird house.—Estimates for a new bird house were submitted for several years prior to the war, but were never favorably acted upon by Congress. The need for a new building for the exhibition of birds is now greater than ever before. The old building was constructed of the cheapest materials many years ago, as a temporary relief, and it is now in a very bad state of repair. It also provides far too little space for the collection and far too little room for visitors; on days of large attendance the public aisles are greatly overcrowded. The collection of birds is one of great importance, containing as it does numerous rare, interesting, and beautiful species; and new arrangements for its care and exhibition to the public should not much longer be delayed.

Respectfully submitted.

N. Hollister,
Superintendent.

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 7.

REPORT ON THE ASTROPHYSICAL OBSERVATORY.

SIR: The Astrophysical Observatory was conducted under the following passage of the sundry civil act, approved March 4, 1921:

Astrophysical Observatory: For maintenance of the Astrophysical Observatory, under the direction of the Smithsonian Institution, including assistants, purchase of necessary books and periodicals, apparatus, making necessary observations in high altitudes, repairs and alterations of buildings, and miscellaneous expenses, $15,500.

The observatory occupies a number of frame structures within an inclosure of about 16,000 square feet south of the Smithsonian administration building at Washington, and also a cement observing station and frame cottage for observers on a plot of 10,000 square feet leased from the Carnegie Solar Observatory on Mount Wilson, Calif.

A new solar observing station on Mount Harqua Hala, Ariz., was erected in July, 1920, at the expense of funds donated for the purpose by Mr. John A. Roebling, of Bernardsville, N. J., and this station has been occupied as a solar radiation observing station by the Astrophysical Observatory since October, 1920.

The present value of the buildings and equipment for the Astrophysical Observatory, owned by the Government, is estimated at $50,000. This estimate contemplates the cost required to replace the outfit for the purposes of the investigation.

WORK OF THE YEAR.

At Washington.—The director, with Mr. Fowle and Mrs. Bond, was engaged much of the year on the preparation and proof reading of Volume IV of the Annals of the Observatory. This quarto volume of 390 pages, including 60 illustrations and 118 pages of numerical tables, covers the work of the years 1912 to 1920, and was published in June, 1922. New apparatus and methods of observing are described and illustrated, and a large mass of solar observations is presented and discussed. Evidence is given of many kinds which indicates the solar variability. Reference is made to applications of the results which have been made by several meteorologists.

In preparation for work proposed for the expedition to Mount Wilson in the summer of 1922, Mr. Aldrich, in consultation with

the director, prepared the sensitive parts of a galvanometer and a vacuum bolometer of usual types for solar work, and also of a vacuum galvanometer and vacuum bolometer of very unusual design suited to observing the energy distribution in the spectra of the stars. These extremely delicate and sensitive instruments required extraordinary skill and patience for their construction and testing. Acknowledgments are due the Director of the Bureau of Standards, the Director of the Nela Research Laboratory, and also Dr. Elihu Thomson, of Lynn, for aiding these preparations.

The instrument making for these new pieces and others required in the expedition to Mount Wilson, including a special spectrometer, plate carrier, and other apparatus, was done by the instrument maker, Mr. A. Kramer.

A great many of the "solar constant" observations made at Mount Harqua Hala, Ariz., were reduced by Mr. Fowle and Mrs. Bond in consultation with the director. Despite our long experience in solar-radiation work, new problems and difficulties still crop up. The publication of the Mount Harqua Hala results has hitherto been withheld so that a comprehensive discussion of them might be made to reveal and correct any systematic errors.

Expedition to Chile.—It became necessary for the director to undertake a visit to Chile to inspect the observing station at Montezuma maintained by the Hodgkins fund for the study of the solar variations, in cooperation with the stations in California and Arizona. Leaving Washington near the end of October, 1921, he spent the month, November 15 to December 15, at the station and returned to Washington early in January, 1922. During the month at Montezuma he revised all the adjustments of apparatus and some of the methods employed there, besides assisting in the daily observations and reductions on 26 days. Silver disk pyrheliometer S. I. No. 5, loaned by the Department of Agriculture for the purpose, was compared with instruments at Montezuma, and before and afterwards with instruments at Washington. No change in the scale of pyrheliometry was disclosed by these comparisons.

Expedition to Mount Wilson.—In June an expedition, including the director and Mr. L. B. Aldrich, went out to Mount Wilson. Four objects were in view. First, to inspect the station at Mount Harqua Hala and compare pyrheliometers there with silver disk pyrheliometer S. I. No. 5, above mentioned, so as to connect the fundamental scales of pyrheliometry in Arizona and Chile. Second, to repeat with all possible precautions and variations of method the determination of the form of the solar spectrum energy curve outside the atmosphere. Third, to undertake preliminary measurements of the distribution of energy in the spectra of the brighter stars.

Fourth, to try further experiments with the collection and storage of solar heat for cooking purposes.

The station on Mount Harqua Hala was visited by the director and found in a highly improved condition owing to the zeal of Mr. Moore, in charge there. The laboratory has been sheathed outside with metal to protect the adobe walls from rain, and painted and embellished within, lightning rods have been installed, a small shop built, wireless telephonic apparatus erected, a garage built at the foot of the mountain trail, and regular weekly mail and supply trips arranged. Solar-constant observations have been made on upward of 70 per cent of the days of the year, and much computing and testing attended to. Comparisons made during and after the director's visit show no change in the scale of pyrheliometry, so that as far as this is concerned the results at Harqua Hala are comparable with those at Montezuma. But from lack of sensitiveness of the galvanometer the energy curves show less detail at Harqua Hala, and this it was decided must be corrected as early as possible to put the two stations on parallel footings.

In conversation with Mr. Moore, the director devised a new improvement of the "short method" which, it was agreed, would promote accuracy while greatly abridging computation. This will be introduced at both stations as soon as the new determination of the form of the solar energy curve outside the atmosphere is worked out.

At Mount Wilson, the time before the end of the fiscal year, June 30, only sufficed for a partial installation of new "solar constant" apparatus replacing that which in 1920 was removed to Harqua Hala. But it may be said by anticipation that later results were secured on the distribution of energy in the spectra of 11 of the brighter stars by bolometric work in connection with the 100-inch telescope, and also that the solar energy curve was traced bolometrically with both glass and rock-salt prisms. With the latter, experiments were made at wave lengths from far down in the ultraviolet to an infra-red wave length of 14 microns, with allowance for stray light and for atmospheric and instrumental transmission.

Unfortunately the cover of the oil reservoir of the solar cooking apparatus had been blown off in a very high wind, and snow having gotten in, much water had leaked into the oil reservoir. After a long time of fruitlessly attempting to boil out this water, the oil and water were at length removed, but not in time to undertake the proposed new experiments before the return of the expedition to Washington in September.

OPINIONS OF THE SOLAR RADIATION WORK.

As the Institution is making great efforts to continue and to improve its solar-radiation measurements, the director felt concerned to invite the opinions of competent critics, in order to know if these

labors seemed quite justified by their probable outcome. Accordingly, in a report to the American representatives of the International Astronomical Union he wrote as follows:

It is the intention of the Smithsonian Institution to continue daily observations at Mount Harqua Hala and Montezuma certainly until July, 1923, at which time it is proposed to consider the state of the work and the results reached with a view to deciding whether it is worth while to continue daily observations of the variability of the sun indefinitely or whether the usefulness of that work is unequal to the trouble and expense involved.

An expression of opinion on the part of those interested in the subject would be of great value to the Smithsonian Institution in making this decision.

In their meeting at Washington, April 3 and 4, 1922, the assembled American representatives, including meteorologists, physicists, and astronomers, passed unanimously, after earnest supporting speeches, the following resolution:

Solar radiation.—Moved: That it is the sense of the American section of the International Astronomical Union that the continuation of the solar-radiation work under the auspices of the Smithsonian Institution in at least two stations is highly desirable, both from an astronomical and a meteorological point of view. Adopted.

Later, in the Congress at Rome, May 2, 1922, the international representatives indorsed this opinion with equal unanimity and earnestness, passing the following resolution:

The section of meteorology of the International Geodetic and Geophysical Union records its appreciation of the excellent work done by the Astrophysical Observatory of the Smithsonian Institution of Washington in determining with a high degree of accuracy the intensity of solar radiation outside the earth's atmosphere. It is of the opinion that the daily values now being obtained at Mount Montezuma, Chile, and Mount Harqua Hala, Ariz., will prove of great value in the solution of certain meteorological problems. It therefore expresses the hope that these determinations may be continued for a considerable period of years.

PROPOSED SOLAR RADIATION STATIONS.

In view of these impartial expert opinions, it is a pleasure to add that Mr. John A. Roebling has made it possible to assure the continuation of the solar-constant stations at Harqua Hala and Montezuma until July, 1925. By that time sufficient data will doubtless be secured to prove whether they ought to be continued longer.

A movement is being made in Australia, led by Rev. E. F. Pigot, of Riverview College, to provide a solar-constant observing station similar to those maintained by the Smithsonian Institution. Funds have been raised there, and a portion of the apparatus has been purchased from the Institution. Also the Meteorological Service of Argentina is proposing to equip its station at La Quiaca for similar observations, in order the more directly to support the regu-

lar weekly long-range forecasts which it bases on solar radiation results. In order to aid these enterprises, the director has designed a full set of solar-constant apparatus, and it is expected that within the next fiscal year two sets will be prepared by contract for the Australian and Argentine stations.

PERSONNEL.

Mr. A. F. Moore, field director at Mount Harqua Hala, was added to the staff of the Astrophysical Observatory on July 1, 1921.

SUMMARY.

The outstanding event of the fiscal year was the publication in June, 1922, of Volume IV of the Annals of the Astrophysical Observatory, covering results from 1912 to 1920. New apparatus and methods are described, a critical survey of the work is given, and long tabular summaries of all solar observations made are included. From these results it is indicated in numerous ways that the sun's output of radiation varies, that the march of its variations depends on the sun's rotation, and that it produces effects of several kinds on terrestrial physics and meteorology. Much progress has been made at the new station on Mount Harqua Hala. Solar-constant observations were made there on over 70 per cent of the days, but are withheld from publication until completely discussed for evidences as to systematic errors. Expeditions were made to Chile and to Mount Wilson.

Respectfully submitted.

C. G. Abbot,
Director.

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 8.

REPORT ON THE INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

SIR: I have the honor to submit the following report on the operations of the United States Bureau of the International Catalogue of Scientific Literature for the fiscal year ending June 30, 1922.

Although the financial conditions of this enterprise were, in common with all other international interests, practically crippled in the beginning of the war, almost all of the regional bureaus have continued to collect and prepare for future publication this index of the world's scientific literature. The activities of this regional bureau have been continued as usual and the data relating to American scientific literature is regularly being prepared ready to forward to the London Central Bureau whenever it is found possible to resume publication.

An international convention is to be held in Brussels beginning July 22, 1922, to determine the future of the catalogue, and the Smithsonian Institution has prepared and will submit to the delegates then present the following statement of its position:

PROPOSALS OF THE SMITHSONIAN INSTITUTION REGARDING THE INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

It is the belief of the Smithsonian Institution:

1. That a classified subject and author index to the literature of science is needed.

2. That no better means exists of attaining the end sought than by carrying out the original plan of the International Catalogue based on international cooperation guided by uniform rules and schedules modified to meet changes in the several sciences and, when possible, broadened in scope to include the allied technical branches of these sciences.

3. That every effort should be made to cooperate with all similar enterprises, including abstracting agencies, existing or projected, not only to prevent duplication of labor but also to better serve the demands of those in need of bibliographic aid.

4. That on account of abnormal conditions still controlling publishing costs and monetary exchange it is probable that actual publication can not be at present resumed unless financial aid is had from some source outside the present organization; however, it is believed:

5. That the international organization should be kept in being through mutual agreement to continue the work of the regional bureaus until such time as it may be economically possible to resume publication. When that

time arrives the stock of complete sets already published should be advertised for sale at a price within the reach of the smaller libraries and institutions, many of whom, although desiring this unique reference work, were prevented from subscribing on account of the high original cost.

Were the price reduced even to one-fourth of the original, stock on hand at that figure represents a sufficient sum to meet all outstanding obligations and leave a surplus for working capital.

The intention in preparing this statement was to take into consideration all existing conditions, and it is believed that if the suggestions are indorsed by the convention, the organization may be kept in being through the continued activities of the various regional bureaus and that when international conditions become more stable the central bureau will be able to meet its financial obligations and resume publication.

When in 1896, 1898, and 1900, the representatives of practically all the civilized nations and foremost scientific institutions met in London to consider and formulate organic rules making possible cooperation between all nations recording scientific investigations, it was their intention not only to produce a catalogue and index of published records as an aid to investigators and bibliographers, but also to establish international cooperation to aid in developing and making available to all those in any way concerned in scientific matters the world's output of scientific records. The material for the 17 annual volumes of the International Catalogue of Scientific Literature issued for the years 1901 to 1914, inclusive, was collected by some 33 regional bureaus and published by the central bureau in London. This unique international cooperative organization, in the main, still exists and although actual publication has, for financial reasons, been suspended pending a more nearly normal condition in international finance and politics, the work of collecting and preparing for publication the records of scientific research is still going on. It would now seem advisable to consider how, until the catalogue can be again published, these records may be made available and to plan for the future improvement and extension of the catalogue service.

The principal methods of furnishing information of the published records of scientific investigations are: Card indexes and periodical bibliographies; abstract journals; year books, cumulative catalogues, and indexes.

To prepare any of these, a complete list of journals is needed but unfortunately no such complete current list now exists. One of the first needs of the catalogue organization, when publication is resumed, will be to bring its own list of journals up to date, the last supplement to the original list having been published in 1904, making the total number of journals listed at that time, 5,627. Since

there is, aside from its use in connection with the catalogue, a decided need and demand for such a list, this bureau is considering the advisability of undertaking the preparation of a revised list of journals, and of soliciting to that end the cooperation of the existing regional bureaus, who would be requested, through the central bureau, to furnish lists of the periodicals published in their several regions.

It is thought that when this material is collected arrangements for publication may be made without cost to the catalogue organization and even that, through such a published list, some financial benefit to the International Catalogue may be derived, but failing in this the labor involved would be justified on account of the need for the current list by the catalogue organization as soon as publication is resumed.

In whatever form bibliographic aid is furnished the method of preparation is the same. In all cases the original publications must be first collected whether they are to be catalogued, indexed, classified, or abstracted, and regular and systematic means must exist to gather all publications, not only periodicals but also single issues. The regional bureaus collectively have advantages in this respect never before available to bibliographers and practically all of the world's scientific literature is through them available. As the catalogue organization was at the London conference of 1920 directed to cooperate with abstracting journals and other similar agencies, it is felt that, although the organization has been disappointed in not yet being able to resume publication, it would be justified in extending its aid to other publishing agencies by furnishing citations to scientific publications being catalogued by the regional bureaus. In return for such aid the catalogue would be benefited by having available abstracts prepared by experts, thus simplifying the work of classification. A final ideal combined organization would, through international cooperation, produce all bibliographic publications of whatever type, and it is felt that when close cooperation is once established between all agencies having kindred aims it will prove essential for their mutual benefit to merge these enterprises into one organization. This plan should aim to eventually include not only the literature of science but also that of related technical industries whose existence and advance depend on the progress made in pure science.

It is realized that to carry out these plans a very extensive organization would be necessary, but when the many great interests involved and their evident unfilled needs are taken into consideration it becomes apparent that some definite effort should be made to consolidate the numerous independent agencies to the end that all

may be benefited. By combined effort much duplication of labor and cost would be saved, and most important of all, bibliographers, students, and industrial agencies would be furnished with prompt and authoritative information regarding the literature of the subjects relating to their several interests.

Very respectfully yours,

LEONARD C. GUNNELL,
Assistant in Charge.

Dr. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 9.

REPORT ON THE LIBRARY.

SIR: I have the honor to submit the following report on the activities of the library of the Smithsonian Institution for the fiscal year ended June 30, 1922.

Possessing more than a million volumes, pamphlets, manuscripts, and charts, acquired chiefly in exchange, the library has continued its steady, ever-increasing growth. There are now, according to the records, 888,128 publications deposited at the Library of Congress and 156,275 belonging to the United States National Museum. Books belonging to other branches of the Institution have been estimated at 35,000.

Its volumes are being constantly borrowed and consulted within the buildings. Interlibrary loans to accredited libraries, where distance permits, are being continued, and in a number of instances arrangements have been made for the photostating of pages from rare volumes not permitted to leave the buildings.

Each day typewritten lists of original scientific articles appearing in periodicals received for the Smithsonian deposit in the Library of Congress are prepared and sent to heads of scientific bureaus under the Institution for their information and for circulation. These daily bibliographical lists, begun last November at the request of the secretary, Dr. Charles D. Walcott, have been well received from the start. Requests from other Government bureaus and research organizations have been made for copies, which it has not been possible to supply.

The facilities of the library have been taxed to the utmost since the beginning of the war for information on various technical subjects. Especially has this been so in connection with aeronautics. In this one subject alone it is safe to say that the Institution, as one of the sources, has been the means of saving the United States Government many thousands of dollars which would have had to be paid if the information relating to the prior art had not been analyzed and available.

SMITHSONIAN MAIN LIBRARY.

As most noteworthy among the accessions of the main library might be mentioned copies of the *Göttingische Gelehrte Anzeigen* for 1758, 1760, 1808, 1813, and 1814, the gift of the Gesellschaft für

Wissenschaften zu Göttingen, and the Transactions of the Royal Dublin Society for 1803 to 1810, the gift of that society.

Material published in oriental languages, while it is not yet received in large quantities as compared with European publications, is continuing to increase, and it is hoped that in the future the Institution may have in the collections at the Library of Congress the most representative collection of this material that can be brought together in this country. The furnishing of English transliterations by the donors, as is done by the Vajiranaña National Library, Bangkok, is of great assistance.

In order that material received for the library may be made available to the public at the earliest possible moment, publications have been transmitted daily, as in years past, to the Smithsonian deposit in the Library of Congress. The number of publications so transmitted during the year was 8,907, consisting of 7,502 complete volumes, 800 parts of volumes, 376 pamphlets, and 229 charts. The accession numbers extended from 537,230 to 539,988. The number of publications transmitted without being entered or accessioned, including Government documents, was 7,213.

Cataloguing.—While the record for volumes catalogued has again been surpassed, it has not been possible during the year to catalogue the remainder of the large accumulation of theses sent during the war from European universities. Following are the year's records:

Volumes catalogued	6,502
Volumes recatalogued	55
Charts catalogued	160
Cards typewritten	4,243
Library of Congress cards filed	592
New titles added	1,614

Exchanges.—The securing of publications in exchange for the completion of sets in the library has been continued, with the following results:

	Wanted.		Secured.	
	Volumes.	Parts.	Volumes.	Parts.
Library of Congress:				
Smithsonian division	1,620	1,184	520	584
Periodical division	35	129	11	28
Order division	30	.....	38	1
United States National Museum	81	83	25	40
	2,766	1,396	594	653

OFFICE LIBRARY.

The growth and increasing value of the office library is perhaps not fully realized. The total number of its accessions as reached this year now numbers 27,100, of which 394 volumes were added during the year. It consists of the following collections: Aeronautical, art room, De Peyster, deposited collections, employees' library, periodicals (back numbers), reading room, reference room.

The aeronautical collection, founded by Samuel Pierpont Langley while Secretary of the Smithsonian Institution, has been since augmented by gifts from Alexander Graham Bell, James Means, Charles D. Walcott, the Aero Club of America, and other individuals and organizations that have had an important part in the development of aeronautics during its pioneer stage. During the present year some 45 volumes were added from the estate of James Means, by gift of his sons Dr. James H. Means and Philip Ainsworth Means.

By the transfer of the employees' library to the east stacks in the main hall of the Smithsonian building, it has been rendered more readily accessible to employees, and additional space for its expansion has been provided. The collection of back numbers of periodicals has been moved to the west stacks.

While the office library is primarily a reference library and books are more often consulted than borrowed, many of the volumes are available for loan purposes, and many employees of the Institution avail themselves of its privileges. The total number of loans for the year was 3,330.

ASTROPHYSICAL OBSERVATORY LIBRARY.

Loans from the Astrophysical Observatory Library are made through the office library, and are included in the records of loans from that library. During the year 79 volumes, 26 parts, and 40 pamphlets were added, and 53 volumes sent to the bindery. The library is primarily a reference library for the use of the staff of the Astrophysical Observatory.

BUREAU OF AMERICAN ETHNOLOGY LIBRARY.

The report of operations of the library of the Bureau of Ethnology will be found in the report of the chief of that bureau. It is administered directly under his care.

UNITED STATES NATIONAL MUSEUM LIBRARY.

The facilities of the Museum Library have been taxed as never before. The number of books loaned was 10,886, and as many more were consulted without being taken from the library.

Valuable material has been donated as in preceding years by friends and members of the staff of the United States National Museum. Among the donors are Messrs. H. S. Barber, August Busck, Austin H. Clark, W. H. Dall, H. G. Dyar, O. P. Hay, Walter Hough, W. R. Maxon, E. G. Mitchell, C. W. Richmond, J. H. Riley, S. A. Rohwer, W. S. Schaus, B. H. Swales, and Dr. and Mrs. Charles D. Walcott. Especially noteworthy are the gifts of Doctor Walcott to the geological and paleontological collections, and the gifts of Dr. William H. Dall to the section of the division of mollusks, numbering 233 titles.

Many of these collections have been received and they have an intimate relation to the library in that the donors were connected with the Museum and brought the collection together during the progress of their researches. The list of donors in the foregoing paragraph will give some idea of the number of collections of this kind that have been added. Special attention should be called to the Iddings and Walcott collections, given during the previous year. These required assorting, arranging, and checking with other publications of the same kind on the shelves, in order to prevent duplication, for which there is not enough room at the present time.

SECTIONAL LIBRARIES.

In order that the volumes and publications of the Museum Library may be readily accessible to the members of the administrative and scientific staff of the Museum, 35 sectional libraries are maintained, namely:

Administration.
Administrative assistant's office.
American archeology.
Anthropology.
Birds.
Botany.
Editor's office.
Fishes.
Foods.
Geology.
Graphic arts.
History.
Invertebrate paleontology.
Mammals.
Marine invertebrates.
Medicine.
Mechanical technology.
Minerals.
Mineral technology.
Mollusks.
Old-world archeology.
Paleobotany.
Photography.
Physical anthropology.
Property clerk's office.
Registrar's office.
Reptiles and batrachians.
Superintendent's office.
Taxidermy.
Textiles.
Vertebrate paleontology.
War library.
Wood technology.

The following statistics have been submitted by Mr. N. P. Scudder, in charge of the library:

Books in the Museum Library:	
Volumes	60,681
Pamphlets	95,594
Total	156,275
Increase:	
Volumes	2,023
Pamphlets	4,185
Total	6,208
Periodicals:	
Parts entered	13,827
Section cards	2,714
Entry cards for new periodicals	271
Cataloguing (not including periodicals):	
Books	860
Pamphlets	4,178
Cards typewritten	6,183
Accession cards	5,214
Section cards	3,655
Books bound	398
Loans (of which 7,012 went to the sections)	10,886
Library of Congress books borrowed	1,583
Library of Congress books returned	1,886
Borrowed from other libraries	106
Returned to other libraries	132

The general library of the Museum is located in the Natural History Building. In order that reference facilities may be readily available to divisions of the Museum located in other buildings, the technological library is maintained in the Arts and Industries Building, and the office library in the Smithsonian Building is at the disposal of Museum divisions located there.

TECHNOLOGICAL LIBRARY.

The technological library, located in the old Museum Building, is continuing the reorganization and rearrangement of its material. The number of loans made during the fiscal year ended was 220. Statistics of the scientific depository catalogue are not at present available, owing to repairs and remodeling now in progress in the library's quarters.

NATIONAL GALLERY OF ART LIBRARY.

Records of the library of the National Gallery of Art are at present kept in the Natural History Library of the Museum, and periodicals entered upon the records and included in periodical statistics

of that library. Accessions for the fiscal year, exclusive of periodicals, covered 32 volumes and 36 pamphlets.

FREER GALLERY OF ART LIBRARY.

Additions to the library of the Freer Gallery of Art during the year numbered 14 volumes. The number of volumes now in the library, exclusive of deposited books, is 127. A number of volumes relating to art have been deposited by the Smithsonian Institution in the Freer Building for use in connection with the collections, among them the set of Serindia, by Sir Aurel Stein, comprising five large quarto volumes with plates in color, presented by the Secretary of State for India.

NATIONAL ZOOLOGICAL PARK LIBRARY.

Since the establishment of a library at the National Zoological Park in 1905, there have been 378 accessions. The number during the fiscal year ended was 15, comprising reports of kindred zoological gardens and parks, and leading zoological works issued during the year.

SUMMARY OF ACCESSIONS.

The accessions for the year, including parts to complete sets, with the exception of additions to the library of the Bureau of American Ethnology, may be summarized as follows:

Branch.	Volumes.	Other publications.	Total.
Astrophysical Observatory	79	66	145
Freer Gallery of Art	14	.....	14
National Gallery of Art	32	36	68
National Zoological Park	15	.....	15
Smithsonian deposit, Library of Congress	7,502	1,405	8,907
Smithsonian office	394	45	439
United States National Museum	2,023	4,185	6,208
Total	10,059	5,737	15,796

Respectfully submitted.

PAUL BROCKETT,
Assistant Librarian.

Dr. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 10.

REPORT ON THE PUBLICATIONS.

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and its branches during the year ending June 30, 1922:

The Institution proper published during the year 9 papers in the series of Miscellaneous Collections, 2 annual reports and pamphlet copies of 55 articles in the appendixes to the reports, a reprint of the Smithsonian Physical Tables, and 5 special publications. The Bureau of American Ethnology published 3 bulletins and 2 annual reports. The United States National Museum issued 1 annual report, 3 volumes of proceedings, 72 separates from the proceedings, 5 bulletins, 2 separate parts of bulletins, and 4 parts of volumes in the series Contributions from the United States National Herbarium.

The total number of publications distributed by the Smithsonian and its branches was 165,196, which includes 251 volumes and separates of the Smithsonian Contributions to Knowledge, 20,777 volumes and separates of the Smithsonian Miscellaneous Collections, 27,263 volumes and separates of the Smithsonian annual reports, 97,806 volumes and separates of the National Museum publications, 14,215 publications of the Bureau of American Ethnology, 3,159 special publications, 706 volumes of the Annals of the Astrophysical Observatory, 64 reports on the Harriman Alaska expedition, 812 reports of the American Historical Association, and 143 publications presented to but not issued by the Smithsonian Institution.

SMITHSONIAN MISCELLANEOUS COLLECTIONS.

Of the Smithsonian Miscellaneous Collections, volume 67, 1 paper was issued; volume 72, 7 papers; volume 73, 1 paper; in all, 9 papers as follows:

VOLUME 67.

No. 7. Cambrian Geology and Paleontology. IV, No. 7. Notes on Structure of Neolenus. By Charles D. Walcott. December 20, 1921. Pp. 365–456, pls. 91–105. (Publ. 2584.)

VOLUME 72.

No. 8. A Review of the Interrelationships of the Cetacea. By Herluf Winge. July 30, 1921. 97 pp. (Publ. 2650.)

No. 10. The Circulatory System in Bone. By J. S. Foote. August 20, 1921. 20 pp., 6 pls. (Publ. 2652.)

No. 11. The Echinoderms as Aberrant Arthropods. By Austin H. Clark. July 20, 1921. 20 pp., 24 figs. (Publ. 2653.)

No. 12. A Study of the Body Temperature of Birds. By Alexander Wetmore. December 30, 1921. 52 pp. (Publ. 2658.)

No. 13. The Melikeron, an Approximately Black-Body Pyranometer. By L. B. Aldrich. January 25, 1922. 11 pp., 5 figs. (Publ. 2662.)

No. 14. A New Sauropod Dinosaur from Ojo Alamo Formation of New Mexico. By Charles W. Gilmore. January 31, 1922. 9 pp., 2 pls. (Publ. 2663.)

No. 15. Explorations and Field Work of the Smithsonian Institution in 1921. May 26, 1922. 128 pp., 132 figs. (Publ. 2669.)

VOLUME 73.

No. 1. Opinions Rendered by the International Commission on Zoological Nomenclature. Opinions 68 to 77. January 31, 1922. 73 pp. (Publ. 2657.)

SMITHSONIAN ANNUAL REPORTS.

REPORT FOR 1919.

The complete volume of the Annual Report of the Board of Regents for 1919, together with the pamphlet copies of the papers in the general appendix, was received from the printer during the year.

Annual Report of the Board of Regents of the Smithsonian Institution, showing operations, expenditures, and condition of the Institution for the year ending June 30, 1919. xii+557 pp., 135 pls., 24 text figs. (Publ. 2590.)

The appendix contained the following papers:

Modern theories of the spiral nebulæ, by Heber D. Curtis.

A determination of the deflection of light by the sun's gravitational field, from observations made at the total eclipse of May 29, 1919, by Sir F. W. Dyson, A. S. Eddington, and C. Davidson.

Wireless telephony, by N. H. Slaughter.

Radium and the electron, by Sir Ernest Rutherford.

The "HD–4." A 70-miler with remarkable possibilities developed at Dr. Graham Bell's laboratories on the Bras d'Or Lakes, by William Washburn Nutting.

Natural resources in their relation to military supplies, by Arthur D. Little.

Glass and some of its problems, by Sir Herbert Jackson.

The functions and ideals of a national geological survey, by F. L. Ransome.

The influence of cold in stimulating the growth of plants, by Frederick V. Coville.

Floral aspects of British Guinea, by A. S. Hitchcock.

Milpa agriculture, a primitive tropical system, by O. F. Cook.

On the extinction of the mammoth, by H. Neuville.

A preliminary study of the relation between geographical distribution and migration, with special reference to the Palaearctic region, by R. Meinertzhagen.

The necessity of State action for the protection of wild birds, by Walter E. Collinge.

Glimpses of desert bird life in the Great Basin, by Harry C. Oberholser.

The Division of Insects in the United States National Museum, by J. M. Aldrich.

The seventeen-year locust, by R. E. Snodgrass.
Entomology and the war, by L. O. Howard.
Two types of southwestern cliff houses, by J. Walter Fewkes.
On the race history and facial characteristics of the aboriginal Americans, by W. H. Holmes.
The opportunity for American archeological research in Palestine, by James A. Montgomery.
The differentiation of mankind into racial types, by Arthur Keith.
The exploration of Manchuria, by Arthur de C. Sowerby.
The origin and beginnings of the Czechoslovak people, by Jindřich Matiegka.
Geographic education in America, by Albert Perry Brigham.
Progress in national land reclamation in the United States, by C. A. Bissell.
Richard Rathbun, by Marcus Benjamin.
A great chemist: Sir William Ramsay, by Ch. Moureu.

REPORT FOR 1920.

The complete volume of the Annual Report of the Regents for 1920 was received from the Public Printer in May, 1922.

Annual Report of the Board of Regents of the Smithsonian Institution, showing operations, expenditures, and condition of the Institution for the year ending June 30, 1920. 704 pp., 230 pls., 105 text figs. (Publ. 2622.)

The appendix contained the following papers:

Studying the sun's heat on mountain peaks in desert lands, by C. G. Abbot.
The habitability of Venus, Mars, and other worlds, by C. G. Abbot.
Giant suns, by H. H. Turner.
A bundle of meteorological paradoxes, by W. J. Humphreys.
The determination of the structure of crystals, by Ralph W. G. Wyckoff.
Dr. Aston's experiments on the mass spectra of the chemical elements, with introduction by C. G. Abbot.
Vitamins, by W. D. Halliburton.
Soil acidity—its nature, measurement, and relation to plant distribution, by Edgar T. Wherry.
The chemistry of the earth's crust, by Henry S. Washington.
Major causes of land and sea oscillations, by E. O. Ulrich.
The Bryozoa, or moss animals, by R. S. Bassler.
The horned dinosaurs, by Charles W. Gilmore.
Rhythm in nature, by F. W. Flattely.
Parasitism and symbiosis in their relation to the problem of evolution, by Maurice Caullery.
Local suppression of agricultural pests by birds, by W. L. McAtee.
The occult senses in birds, by Herbert H. Beck.
Adventures in the life of a fiddler crab, by O. W. Hyman.
The senses of insects, by N. E. McIndoo.
The resplendent shield-bearer and the ribbed cocoon-maker: Two insect inhabitants of the orchard, by R. E. Snodgrass.
The origin of insect societies, by Auguste Lameere.
The botanical gardens of Jamaica, by William R. Maxon.
Daturas of the old world and new: An account of their narcotic properties and their use in oracular and initiatory ceremonies, by William E. Safford.
Effect of the relative length of day and night on flowering and fruiting of plants, by W. W. Garner and H. A. Allard.
Fire worship of the Hopi Indians, by J. Walter Fewkes.

Racial groups and figures in the Natural History Building of the United States National Museum, by Walter Hough.
Notes on the dances, music, and songs of the ancient and modern Mexicans, by Auguste Genin.
The Ralph Cross Johnson collection in the National Gallery at Washington, D. C., by George B. Rose.

REPORT FOR 1921.

The report of the executive committee and proceedings of the Board of Regents of the Institution, and the report of the secretary, both forming part of the annual report of the Board of Regents to Congress, were issued in pamphlet form in November, 1921.

Report of the executive committee and proceedings of the Board of Regents of the Smithsonian Institution for the year ending June 30, 1921. 18 pp. (Publ. 2660.)
Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1921. 119 pp. (Publ. 2659.)

The general appendix to this report, which was in press at the close of the year, contains the following papers:

The daily influence of astronomy, by W. W. Campbell.
Cosmogony and stellar evolution, by J. H. Jeans.
The diameters of the stars, by A. Danjon.
Isotopes and atomic weights, by F. W. Aston.
Modifying our ideas of nature: The Einstein theory of relativity, by Henry Norris Russell.
The alkali problem in irrigation, by Carl S. Scofield.
An outline of geophysical-chemical problems, by Robert B. Sosman.
The yielding of the earth's crust, by William Bowie.
The age of the earth, by the Right Hon. Lord Rayleigh, W. J. Sollas, J. W. Gregory, and Harold Jeffreys.
The department of geology of the U. S. National Museum, by George P. Merrill.
Some observations on the natural history of Costa Rica, by Robert Ridgway.
The historic development of the evolutionary idea, by Branislav Petronievics.
The heredity of acquired characters, by L. Cuénot.
Breeding habits, development, and birth of the opossum, by Carl Hartman.
Some preliminary remarks on the velocity of migratory flight among birds, with special reference to the Palaearctic region, by R. Meinertzhagen.
A botanical reconnaissance in southeastern Asia, by A. S. Hitchcock.
Ant acacias and acacia ants of Mexico and Central America, by W. E. Safford.
The fall webworm, by R. E. Snodgrass.
Collecting insects on Mount Rainier, by A. L. Melander.
The science of man: Its needs and prospects, by Karl Pearson.
Pigmentation in the old Americans, with notes on graying and loss of hair, by Aleš Hrdlička.
Ancestor worship of the Hopi Indians, by J. Walter Fewkes.
The Indian in literature, by Herman F. C. Ten Kate.
Leopard-men in the Naga Hills, by J. H. Hutton.
A new era in Palestine exploration, by Elihu Grant.
The alimentary education of children, by Marcel Labbé.
A fifty-year sketch history of medical entomology, by L. O. Howard.
Laid and wove, by Dard Hunter.
Lead, by Carl W. Mitman.
William Crawford Gorgas, by Robert E. Noble.

SPECIAL PUBLICATIONS.

The following special publications were issued during the year:

Catalogue of the Herbert Ward African Collection. 8 pp., 12 figs. (Publ. "AT.")

Classified List of Smithsonian Publications Available April 15, 1922. Compiled by Helen Munroe. May 1, 1922. 30 pp. (Publ. 2670.)

Title page and contents of volume 69, Smithsonian Miscellaneous Collections. (Publ. 2654.)

Title page and contents of volume 70, Smithsonian Miscellaneous Collections. (Publ. 2655.)

Title page and contents of volume 71, Smithsonian Miscellaneous Collections. (Publ. 2656.)

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM.

The publications of the National Museum are: (*a*) The annual report, (*b*) the Proceedings of the United States National Museum, and (c) the Bulletin of the United States National Museum, which includes the Contributions from the United States National Herbarium. The editorship of these publications is vested in Dr. Marcus Benjamin.

During the year ending June 30, 1922, the Museum published 1 annual report, 3 volumes of proceedings, 5 complete bulletins, 2 parts of bulletins, 4 parts of volumes in the series Contributions from the United States National Herbarium, and 72 separates from the proceedings.

The issues of the bulletin were as follows:

Bulletin 100, volume 4. Contributions to the Biology of the Philippine Archipelago and Adjacent Regions. Volume 4: Foraminifera of the Philippine and Adjacent Seas. By Joseph A. Cushman.

Bulletin 113. Life Histories of North American Gulls and Terns. Order Longipennes. By Arthur Cleveland Bent.

Bulletin 114. A revision of the King Snakes: Genus Lampropeltis. By Frank N. Blanchard.

Bulletin 118. Handbook and Descriptive Catalogue of the Collections of Gems and Precious Stones in the United States National Museum. By George P. Merrill, assisted by Margaret W. Moodey and Edgar T. Wherry.

Bulletin 119. Catalogue of the Mechanical Engineering Collection in the United States National Museum. Motors, Locomotives, and Self-propelled Vehicles. By Carl W. Mitman.

Of the separate papers of bulletins, the following were issued:

Bulletin 82. A Monograph of the Existing Crinoids. Volume 1.—The Comatulids. Part 2. By Austin Hobart Clark.

Bulletin 104. The Foraminifera of the Atlantic Ocean. Part 3. Textulariidae. By Joseph Augustine Cushman.

Of the separate papers of the Contributions from the United States National Herbarium, the following were issued:

Volume 20, part 11. The Identification of Berberis Aquifolium and Berberis repens. By Charles V. Piper.

Volume 20, part 12. New or Noteworthy Plants from Colombia and Central America—8. By Henry Pittier.

Volume 22, part 6. Grasses of British Guiana. By A. S. Hitchcock.

Volume 24, part 1. New Plants from Guatemala and Honduras. By S. F. Blake.

Of the separates from the proceedings, 25 were from volume 59, 26 from volume 60, and 21 from volume 61.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY.

The publications of the bureau are described in detail in Appendix 4 of this report. The editorial work of the bureau is under the direction of Mr. Stanley Searles, editor.

During the past year two annual reports, the thirty-fifth and the thirty-sixth, and three bulletins were published, as follows:

Thirty-fifth Annual Report. Accompanying paper: Ethnology of the Kwakiutl (Boas). Pts. 1 and 2. 1,481 pp.

Thirty-sixth Annual Report. Accompanying paper: The Osage Tribe: Rite of the Chiefs; Saying of the Ancient Men (La Flesche). 604 pp., 23 pls.

Bulletin 73. Early History of the Creek Indians and Their Neighbors (Swanton). 492 pp., 10 pls.

Bulletin 74. Excavation of a Site at Santiago Ahuitzotla, D. F. Mexico (Tozzer). 56 pp., 19 pls.

Bulletin 75. Northern Ute Music (Densmore). 213 pp., 16 pls.

There were in press or in preparation at the close of the year four annual reports and six bulletins, as follows:

Thirty-fourth Annual Report. Accompanying paper: A Prehistoric Island Culture Area of America (Fewkes).

Thirty-seventh Annual Report. Accompanying paper: The Winnebago Tribe (Radin).

Thirty-eighth Annual Report. Accompanying paper: An Introductory Study of the Arts, Crafts, and Customs of the Guinea Indians (Roth).

Thirty-ninth Annual Report. Accompanying paper: The Osage Tribe: The Rite of Vigil (La Flesche).

Bulletin 76. Archeological Investigations (Fowke).

Bulletin 77. Villages of the Algonquian, Siouan, and Caddoan Tribes west of the Mississippi (Bushnell).

Bulletin 78. Handbook of the Indians of California (Kroeber).

Bulletin 79. Blood Revenge, War, and Victory Feasts among the Jibaro Indians of Eastern Ecuador (Karsten).

Bulletin 80. Mandan and Hidatsa Music (Densmore).

Bulletin 81. Excavations in the Chama Valley, N. Mex. (Jeancon).

PUBLICATIONS OF THE ASTROPHYSICAL OBSERVATORY.

The fourth volume of the annals of the Astrophysical Observatory, covering the work of the observatory from 1913 to 1920, was issued in June, 1922.

Volume IV. Annals of the Astrophysical Observatory, by C. G. Abbot, F. E. Fowle, and L. B. Aldrich. June 24, 1922. 390 pp., 2 pls. (Publ. 2661.)

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION.

The annual reports of the American Historical Association are transmitted by the association to the Secretary of the Smithsonian Institution, and are communicated to Congress under provisions of the act of incorporation of the association.

The annual report for 1917 and the annual report for 1918, volumes 1 and 2, together with the supplemental volume to this report entitled "Writings on American History," were published during the year.

The annual report for 1919, volumes 1 and 2, and the supplemental volumes to the reports for 1919 and 1920 were in press at the close of the year.

REPORT OF THE NATIONAL SOCIETY OF THE DAUGHTERS OF THE AMERICAN REVOLUTION.

The manuscript of the Twenty-fourth Annual Report of the National Society of the Daughters of the American Revolution was transmitted to Congress according to law on January 4, 1922.

THE SMITHSONIAN ADVISORY COMMITTEE ON PRINTING AND PUBLICATION.

The Smithsonian advisory committee on printing and publication passes upon all manuscripts offered for publication by the Institution or its branches and considers all forms of routine, blanks, and such other matters as pertain to printing and publication. Eight meetings were held during the year and 100 manuscripts were acted upon.

Respectfully submitted.

W. P. True,
Editor.

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1922.

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds, receipts, and disbursements of the institution and a statement of the appropriations by Congress for the National Museum, the International Exchanges, the Bureau of American Ethnology, the National Zoological Park, the Astrophysical Observatory, the International Catalogue of Scientific Literature, and the National Gallery of Art, for the year ending June 30, 1922:

SMITHSONIAN INSTITUTION.

Condition of the fund July 1, 1922.

The sum of $1,000,000 deposited in the Treasury of the United States under act of Congress is a permanent fund, having been accumulated by the deposit of savings and bequests from time to time. Subsequent bequests and gifts and the income therefrom, when so required, are invested in approved securities. The several specific funds so accumulated are now constituted as follows and classed as the consolidated fund:

Hodgkins general fund	$37,275.00
Rhees fund	199.00
Avery fund	20,489.80
Addison T. Reid fund	3,679.00
Lucy T. and George W. Poore fund	8,444.00
George H. Sanford fund	374.00
Smithson fund	1,429.14
Chamberlain fund	35,000.00
Bruce Hughes fund	9,894.76
Hamilton fund	500.00
Lucy H. Baird fund	1,260.58
Virginia Purdy Bacon fund	46,900.00
Charles D. and Mary Vaux Walcott research fund	11,520.00
Caroline Henry fund	1,000.00
Total consolidated fund	177,965.28

One piece of improved real estate, at 140 East Capitol Street, Washington, D. C., forming a part of the original bequest of the late

Robert Stanton Avery, is still retained by the institution and yields a nominal revenue.

The institution has further received from the executors of the Charles L. Freer estate shares of Parke, Davis & Co. representing a book value of $589,140, which, in turn, have been temporarily deposited with a local trust company as collateral to secure a loan for the purpose of liquidating inheritance and other taxes, which as residuary legatee of the Freer estate the institution is required to pay. This loan is being paid as revenues will permit.

The total amount of dividends and interest received by the institution from this estate during the year for all purposes was $83,127.36. The further sum of $55,823.44 was transferred to the books of the institution for account of the Freer building fund.

The itemized report of the auditor is filed in the office of the Secretary.

Detailed survey of financial operations.

Ordinary receipts:	
Cash balance on hand July 1, 1921	$11,229.34
Income from miscellaneous sources available for general purposes	56,361.40
International Exchanges, repayments to the institution for specific purposes	5,510.74
Total resources for ordinary purposes	73,101.48
Ordinary expenditures:	
Care and repair of buildings	7,124.46
Furniture and fixtures	1,466.73
General administration	25,338.83
Library	2,893.23
Publications (comprising preparation, printing, and distribution)	14,325.63
Researches and explorations	3,847.90
International Exchanges	7,752.39
Total ordinary expenditures	62,749.17
Advances and repayments for field expenses and other temporary transactions during the year:	
Advances	13,886.62
Repayments	11,308.12
Difference	2,578.50

The above difference will be adjusted in due course.

RECEIPTS AND EXPENDITURES FOR SPECIFIC OBJECTS.

Receipts:	
Avery fund	$1,863.50
Harriman trust fund	12,400.00
Hodgkins fund	6,862.00
Hamilton fund	173.00
Rhees fund	43.59
Addison T. Reid fund	809.96
Lucy T. and George W. Poore fund	1,947.95
George H. Sanford fund	81.36

Receipts—Continued.	
Bruce Hughes fund	$2,418.88
Swales fund	400.00
Caroline Henry fund	1,023.00
Loeb fund	1,253.04
W. L. Abbott, researches	2,000.00
John A. Roebling, solar research	15,771.38
Frances Lea Chamberlain fund	1,610.00
Lucy H. Baird fund	55.38
Virginia Purdy Bacon fund	2,137.00
Total	50,850.04
Expenditures:	
John A. Roebling fund, for solar research	8,127.86
Swales fund, for specimens	346.73
Chamberlain fund, for specimens	1,040.39
Hodgkins fund, for solar research	3,417.04
Harriman trust fund, for researches and specimens	11,038.84
Rhees fund, invested	43.00
Avery fund, invested	2,050.00
Addison T. Reid fund, invested	819.00
Lucy T. and George W. Poore fund, invested	1,784.00
Lucy T. and George W. Poore fund, taxes	281.21
George H. Sanford fund, invested	80.00
Lucy H. Baird fund, invested	94.00
Bruce Hughes fund, invested	1,152.83
Bruce Hughes fund, expended	28.34
Virginia Purdy Bacon fund, invested	1,900.00
Caroline Henry fund, invested	1,000.00
Loeb fund, expended	350.00
Total	33,553.24

RECEIPTS AND EXPENDITURES PERTAINING TO THE CHARLES L. FREER BEQUEST.

Receipts:	
Interest and dividends	$83,127.36
Building construction and equipment	55,823.44
Total receipts	138,950.80
Expenditures:	
Payment of temporary loan to settle estate and for purposes designated by the testator, including purchase of art objects	85,034.48
Building construction and equipment	32,122.78
Total expenditures	117,157.26

SUMMARY.

RECEIPTS.

Ordinary income for general objects, including cash balance at beginning of year	$73,101.48
Revenue and principal of funds conveyed for specific purposes, except the Freer bequest	50,850.04
Freer bequest	138,950.80
Total	262,902.32

EXPENDITURES.

General objects of the institution	$62,749.17
Expenditures for specific purposes, except the Freer bequest	33,553.24
Advances for field expenses	2,578.50
Freer bequest	117,157.26
Cash deposited on time at 3 per cent	40,500.00
Cash balance June 30, 1922	6,364.15
Total	262,902.32

All payments are made by check, signed by the secretary of the institution, on the Treasurer of the United States, and all revenues are deposited to the credit of the same account, except in some instances small deposits are placed in bank for convenience of collection and later are withdrawn in round amounts and deposited in the Treasury.

The practice of investing temporarily idle funds in time deposits has proven highly satisfactory. During the year the interest derived from this source, together with other similar items, has resulted in a total of $2,033.93.

The following appropriations were intrusted by Congress to the care of the Smithsonian Institution for the fiscal year 1922:

Bureau.		Appropriation.
International Exchanges		$50,000.00
American Ethnology		46,000.00
International Catalogue of Scientific Literature		7,500.00
Astrophysical Observatory		15,500.00
National Museum:		
Furniture and fixtures	$20,000.00	
Heating and lighting	70,000.00	
Heating and lighting (deficiency)	4,000.00	
Preservation of collections	312,620.00	
Preservation of collections (deficiency)	15.84	
Building repairs	10,000.00	
Books	2,000.00	
Books (deficiency)	3.02	
Postage	500.00	
		419,138.86
National Gallery of Art		15,000.00
National Zoological Park		125,000.00
Additional land for Zoological Park		2,500.00
Increase of compensation, indefinite.		
Total		680,638.86

Respectfully submitted.

GEO. GRAY,
HENRY WHITE,
JOHN B. HENDERSON,
Executive Committee.

PROCEEDINGS OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE FISCAL YEAR ENDING JUNE 30, 1922.

ANNUAL MEETING, DECEMBER 8, 1921.

Present: The Hon. Calvin Coolidge, Vice President of the United States, chancellor, in the chair; Chief Justice William H. Taft; Senator A. Owsley Stanley; Representative Frank L. Greene; Representative John A. Elston; Dr. A. Graham Bell; Hon. George Gray; Mr. John B. Henderson; Hon. Henry White; Mr. Robert S. Brookings; and the secretary, Mr. Charles D. Walcott.

NEW REGENT.

The secretary stated that the organic act establishing the Smithsonian Institution provides that the Chief Justice of the United States shall be ex officio a regent of the institution. He had the pleasure, therefore, of announcing that Hon. William Howard Taft was now a member of the board.

ACKNOWLEDGMENT OF RESOLUTIONS.

The secretary read the following letter from Mrs. Edward Douglass White:

JUNE 2, 1921.

MY DEAR MR. WALCOTT: May I not ask you to convey to the Board of Regents my sincere thanks and grateful appreciation of the generous tribute to my beloved husband, expressed in their resolutions, a copy of which you were so kind as to send me.

Permit me also to thank you personally for the kind sympathy conveyed by your letter of transmittal.

Very sincerely,

MRS. EDWARD DOUGLASS WHITE.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURE.

Judge Gray, chairman of the executive committee, offered the following resolution, which was adopted:

Resolved, That the income of the institution for the fiscal year ending June 30, 1923, be appropriated for the service of the institution, to be expended by the secretary with the advice of the executive committee, with full discretion on the part of the secretary as to items.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

The secretary presented, in printed form, the annual report of the executive committee, giving a statement of the financial condition of the institution for the fiscal year ending June 30, 1921.

On motion, the report was accepted.

ANNUAL REPORT OF THE PERMANENT COMMITTEE.

At the request of Judge Gray the secretary submitted the following report:

Hodgkins fund.—Researches in solar radiation are being continued at the station on the Montezuma Mountain, in Chile, at an altitude of between 9,000 and 10,000 feet. As stated in previous reports, the expense of the maintenance of this station is borne chiefly from an allotment of $5,000 annually from the Hodgkins special fund. The work is under the direction of Dr. Charles G. Abbot, assistant secretary of the institution and director of the Astrophysical Observatory.

Roebling contributions.—Mr. John A. Roebling, of New Jersey, has generously contributed to date the sum of $29,150 in connection with certain phases of the work of the solar research stations in Chile and Arizona. Sufficient funds have been thus provided for the year, and good progress has been made in the work.

Freer estate.—

Building fund:	
Receipts	$1,337,984.68
Expenditures	1,289,772.37
Balance on hand	48,212.31

Other provisions: Mr. Freer's bequest to the institution provides certain shares of stock for specified funds to the extent of $353,004.75. Of the residuary estate there have been received $900,000, the income of which will not be available for the purchase of additions to the collections for several years.

Avery bequest.—The total amount of this bequest is now $33,424.80. One piece of improved real estate, situated on East Capitol Street, remains unsold.

Poore bequest.—Several pieces of land remain, but will be sold as favorable offers are received. According to the terms of the will of the testator, George W. Poore, this fund must accumulate until it reaches a total of $250,000. It now amounts to $34,230.

Virginia Purdy Bacon bequest.—This bequest, which will probably total $50,000, was given to establish the Walter Rathbone Bacon (traveling) scholarship for the study of the fauna of countries other than the United States. Forty-five thousand dollars has been transferred to the institution in the form of bonds and preferred stock of excellent value and stability.

Bruce Hughes bequest.—This fund, which was given for the purpose of establishing the Hughes alcove, now totals $11,170.99.

Frances Lea Chamberlain funds.—Two bequests were made by Dr. Leander T. Chamberlain as a memorial to his wife, Frances Lea. One of these, of $10,000, was received in 1915, and the other, of $25,000, in June, 1921. The income from these funds is to be expended in the improvement and increase of the Isaac Lea collections of "Mollusks" and of "Gems and gem material" now in the National Museum.

Addison T. Reid bequest.—This bequest, which is to found a chair in biology as a memorial to the testator's grandfather, Asher Tunis, now amounts to $14,260. The bequest was subject to the condition that the income was to be paid in three shares to certain named beneficiaries until their death, when the principal of each share, with accumulations, was to come to the institution. Two of these beneficiaries have died, and their shares have been received. The remaining share represents approximately $5,000.

Miscellaneous bequests.—A number of small bequests, aggregating several thousand dollars, have been included in the consolidated fund.

Residual bequests.—The institution will receive the following bequests, subject to the death of certain beneficiaries: The Joseph White Sprague bequest; the Lucy Hunter Baird bequest; the Riter Fitzgerald bequest; and the Caroline Henry bequest. From the last named estate an additional cash bequest of $1,000 has been received.

Consolidated fund.—This is composed of funds received in excess of the $1,000,000 deposited in the Treasury of the United States under the authority of the organic act. It includes several of the bequests referred to above, and now amounts to $157,562.05.

Mr. Henderson offered the following resolution, which was adopted:

Resolved, That the Board of Regents of the Smithsonian Institution accepts the report of the permanent committee and approves and ratifies the actions taken by the committee since the last annual meeting of the board.

ANNUAL REPORT OF THE SECRETARY.

The secretary submitted, with explanatory remarks, his report for the fiscal year ending June 30, 1921, printed copies of which had already been supplied the regents.

On motion, the report was accepted.

ANNUAL REPORT OF THE NATIONAL GALLERY OF ART COMMISSION.

At a meeting held May 27, 1921, the Board of Regents of the Smithsonian Institution established a National Gallery of Art Commission, to consist of five public men interested in the fine arts, five experts in the fine arts, five artists, and the Secretary of the Smithsonian Institution ex officio. The primary purpose of the commission is to promote the administration, development, and utilization of the National Gallery of Art, including the acquisition of material of high quality representing the fine arts, and the study of the best methods of exhibiting art works to the public and their utilization for instruction.

The commission has held several meetings, at the first of which officers were elected and the various committees called for in the plan of organization appointed. The details of the membership of the commission and of its committees, and also of the business transacted during the year, will be found in the appendix on the National Gallery of Art in the annual report of the Secretary of the Smithsonian Institution for the year ending June 30, 1922.

On motion, the report was accepted.

The secretary reported the resignation of Mr. Charles A. Platt as a member of the commission, and stated that Mr. A. Kingsley Porter had been suggested to fill the vacancy. On nomination he was elected.

FREER ESTATE MATTERS.

The secretary said that he had already called attention to the financial condition of the Freer bequest and funds as detailed in the permanent committee's report. The board was aware that the State of Michigan had levied a State inheritance tax against the residuary estate of Mr. Freer. This tax, which was considerably more than $400,000, was also subject to a penalty tax, so that the total amount was probably as much as $480,000.

The executors were anxious to settle the estate and had suggested a plan which would save as much of the residuary portion as possible for the institution. This plan had been taken up by the permanent committee, and after careful consideration the method of settlement had been outlined in a series of resolutions which were submitted in detail to the board.

After discussion, the resolutions were adopted.

ZOOLOGICAL PARK APPROPRIATION.

The secretary said that in the alternative budget the appropriation for the National Zoological Park has been taken from among the Smithsonian branches, and has been included among the appropriations for the District of Columbia, for the reason, as stated, that 60 per cent of the appropriation for the park is charged against the revenue of the District.

The transferring of this appropriation to the District bill would not necessarily make any change in the administration of the park, which, in the act of organization, is specifically placed under the direction of the Board of Regents, the appropriations therefor to be disbursed by the disbursing officer of the institution. It might, however, give rise to misunderstandings and difficulties in its practical administration.

The secretary added that he was not asking action on the part of the board at this time.

THE SECRETARY'S SUPPLEMENTAL STATEMENT.

The secretary presented a supplemental statement covering the various activities of the institution since the printing of the annual report. These will be described in detail in his printed report for 1922.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1922

ADVERTISEMENT.

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previous had been issued by well-known private publishing firms, the secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1922.

WHO WILL PROMOTE SCIENCE?

By C. G. Abbot.

President Harding, in transmitting the annual Federal budget to Congress, on December 4, 1922, proposed a budget of approximately three billion dollars for the fiscal year ending June 30, 1924. Of this sum, he pointed out that two-thirds were necessary on account of practically fixed charges, such as the public debt, national defense, pensions, World War allowances, Federal aid, and there was left about one billion dollars in charges subject to administrative control. Analyzing these latter charges, he at length came to the item $10,619,456 for science and research and a little after took up the question of further cuts in Government appropriations, saying:

> Can there be a reasonable expectation for further considerable reduction in governmental expenditures in the near future? This question is no doubt upon the lips of many. The burden of taxation caused by the World War has borne heavily upon us all, and it has been the earnest desire of the Government to reduce this burden to the minimum consistent with a proper functioning of the Federal services. We have seen, however, that approximately two-thirds of the taxes collected go to pay certain fixed charges, over the expenditure of which there can be exercised little or no administrative control * * *.
>
> After deducting these items there is left, as has been shown, approximately only one billion dollars, out of which these normal operating expenses of the Government must be paid. It is against this group of expenditures that the retrenchment policy of the Government has been directed.

After discussing some of the items included in this category, he continues:

> There is * * * a rapidly broadening field of Government expenditure which may be discussed with profit to us all. I refer to expenditures which are being made from appropriations for Federal aid in lines of research, improvement, and development, which, while having no direct connection with the operations of the business of Government, have grown to become a recognized part of its activities * * *. There is question as to how far the Government should participate in these extraneous activities, and I am frank to say that an answer to the question as to whether we can look forward to any further material reduction in the expenditures of the Government in future years depends largely upon whether or not there will be a curtailment or expansion of these activities, which have already added greatly to the annual drafts upon the Treasury of the United States.

From these authoritative figures we learn that the Federal Government is appropriating one-third of 1 per cent of its annual budget for science and research, and that in the pursuit of economy it may be possible that this and other public welfare items, regarded as extraneous to the true business of Government, may be subject to future reduction. This raises the question: Should science be supported at all; and if so, by whom?

People fall in several classes according to their outlook upon science. There are those who hold that because "A little knowledge is a dangerous thing" a great deal of knowledge is a calamity. Over against this is the little group of those who love knowledge for its own sake as the soul of civilization and a great prize worth sacrifice to gain. Between these extremes lies the great body of the public whose first question about a new discovery is "What good is it?"

If it were possible to change this attitude of the man in the street to that of faith in the future value of all truth, such as indeed past experience warrants, there would remain no reason to write this article. Government would then support research by more than one-third of 1 per cent of its budget, because the voters would demand it, and men of wealth would increasingly bequeath new foundations for scientific research or strengthen existing ones.

It is a pity that the man who loves and creates knowledge should be so remote from the man who creates wealth. The press of our country does little to bridge the chasm between the man of science and the public, not because the papers are not eager to print every new thing—far from it. But, unlike the press of many foreign countries, and notably of the British Australasian colonies, our writers place small value on accuracy and appear by comparison with Australian reporters to belittle the intelligence and good taste of their readers. Few news reporters of the United States are qualified themselves to write on science, but when interviewing a research man on the subject of his latest discovery they seldom use shorthand. They take a few notes in a longhand code, but their prime object is to pry for something sensational to associate with the story. When the piece appears the sensation is the kite, the discovery no more than a mutilated tail. The discoverer shudders and vows it shall be the last interview he will grant. His fellow investigators, seeing the news story, may make a shrewd guess as to what he has done, but the public, with little knowledge of the subject as a guide, is led ever deeper into the Alice in Wonderland world which our newspapers invent. There are some gallant exceptions in the American press. More power to them!

Doubtless the blame should alight partly upon the man of science. For if he will not or can not present his news in an interesting way

the reporters will do it for him, accuracy to the contrary notwithstanding, if they can scent out any whiff of human interest in it. In good conscience it behooves him to practice up in the art of presenting the heart of things. Even his fellow men of science would appreciate that when it comes to listening to him in a meeting.

There is a time-worn illustration which strikes harder now than when first uttered, because the faith of the man of science has been so overwhelmingly justified. A member of the Government to whom Michael Faraday was showing a new experiment in electricity said slightingly, "Very curious, but of what use is it?" "By and by, my lord," replied Faraday, "you may tax it."

Not everybody who makes valuable discoveries is a Faraday, yet the man in the street expects every discoverer to be also a prophet, and not only a prophet, but endowed with a gift of tongues, so that when asked "of what use is the new result?" he shall go beyond the answer of him who replied: "Of what use, madame, is a new-born infant?" and be able to describe the whole family tree of the descendants of the infant discovery in terms so simple and so clear that he who runs may read.

If investigation had always been limited to subjects promising to have utility, we should still be in the dark ages. The enlightenment of the human mind brought about by the study of astronomy, for instance, has a value not to be measured by dollars and cents, but by the safety of life and property from religious persecution and by the advance from superstition and ignorant fear of nature. On the other hand, it would be easy to cite many investigations of apparently merely curious and trivial phenomena which later on came to have high commercial utility. One will suffice. Thirty years ago no "practical man" would have dreamed of investigating the conduction of electricity through rarefied gases. Röntgen's discovery of X rays was not in the least influenced by utility, but came out of pure research work in that field. Think of X-ray hospital work nowadays! Moreover, every department store carries radio-telephone outfits, with their thermionic amplifiers, which also are the children of that same line of pure research.

But after all, "what further need have we of witnesses?" Hertzian waves have become radio; Pasteur's bacilli have led up to the Mayo brothers' surgery and the abolishment of yellow fever; Faraday's and Henry's electromagnets have become dynamos and telegraphs, and the whole world is revolutionized in a century by the discoverers who worked not for utilities but for knowledge. Yet it is a mean, stunted mind that sees only things like autos and electric lights as the foremost rewards and justification of science. What the sculpture of Phidias, the painting of Raphael, the music of

Beethoven, the language of the Bible, are to the finer departments of the mind such also and quite as wholesome in their influence on private life and public conduct are those studies of the atoms, the universe, and the march of life, which form science.

An investment in science is as sure as a United States bond. All history, and especially the history of our own time, proves it. If a man of millions coming up to the time when he should put his house in order for his departure is so clannish as to wish to give all to his heirs, caring nothing for any other living beings in this world and not even regarding a monument to himself, he would accomplish his purpose more completely by investing 5 per cent of his fortune to promote scientific research. For his descendants will suffer cancers and will desire luxuries like other men. The only way that those pangs may be avoided and those desires gratified is by the making and utilization of scientific discoveries. If means are provided, such discoveries will be made and applied. The past proves it. No gift of prophecy is needed to know that the future progress of knowledge will benefit both rich and poor.

Science should be supported, but by whom, and to whom should the wealth flow to promote it? President Harding's message shows that for the present Federal support is scanty, and for the future uncertain. The State governments differ in their liberality, but on the whole, like the Nation, so the States. There are the universities and schools of higher learning whose scientific output is inspiring. But listen to the general cry from them! Enormous enrollment, pinching salaries, time and energy consumed in teaching. They can do little more without endowments specifically given them for research purposes. They can not devote more of their present means to scientific experiments, though they might employ additional sums highly creditably if such were intrusted to them. Then there are the great manufacturing corporations. All the more enlightened of them maintain now scientific laboratories, but primarily they are carried on for utilitarian ends closely associated with the problems of manufacture, and the results are apt to be withheld in part from public knowledge. One is not aware that a single one of these organizations promotes, for example, the progress of mathematics, although all of them make use of it as a tool, and without the progress of mathematics beyond its present attainments the more profound engineering problems of the future will lack means of solution.

In short, research with the universities, colleges, and corporations is a secondary by-product, associated in the former with teaching, in the latter with manufacturing. The professors may have the spirit inclined to seek knowledge wherever it leads, but they lack the opportunity. The corporation employees drive knowledge where

wealth is to be gained. These agencies are not enough. There needs to be the broad research organizations founded to survey the field of knowledge, direct researches so as to fill its gaps and extend its borders without prejudice in favor of immediate wealth-producing utilities. They must also publish and diffuse accurate and inspiring knowledge among the people and find out and give opportunities for work to the exceptional men and women—the Faradays and the Curies of the future.

There are already several such establishments well organized, ably directed, and enjoying the advice and counsel of the most well-informed and far-sighted of our men of science and philanthropy. Men of wealth have founded them as memorials in most cases, giving their own names, very naturally, to secure perpetual remembrance. The time will come when it would be foolish and hurtful to add to the number of such institutions, but not soon when it will cease to be needful to add to their financial resources.

There should be no hesitation on account of a name. Some of these institutions, notably the oldest, the Smithsonian, have carried their names so long that they are now no longer primarily associated with the founders, but rather with the noble work which the institutions have done, so that they have become household and national rather than family names. A modern giver to such an old institution may, however, well require that his own name should be attached to that part of the foundation which he donates, and thus he may provide himself with a worthy memorial.

But let him think seriously in doing so before tying up his gift with restrictions as to the character of the expenditures to be promoted thereby. The giver is but one man, and however wide his knowledge that of the institution is wider, more comprehensive, and discerning. Times change; research is alive and growing. Let there be trust in the wisest use of the funds by the enlightened executive of the institution rather than a restriction of scope. Otherwise the institution is apt to be loaded with a series of white elephants and oppressed to stagnation by the management of them, whereas if the gifts were free from oppressive conditions the right things could be done to promote useful knowledge.

Colleges have loyal alumni, some of great wealth competent to endow large foundations bearing their names. But the alumni as a body, without hope of individual perpetual remembrance give great sums to rescue the college in its times of need. Research institutions lack these loyal constituencies. How can they, then, with dignity lay bare their poverty or hope for adequate relief? Can their officers, so imbued with veneration and loyalty that they serve a lifetime for a pittance, eked out by literary or teaching work in recreation hours,

confide their own straits, the paucity of research funds, the starvation wages of the employees, and, as it might seem, ask alms of the general world?

Really, the world owes research men a living. But the plain fact is that they not only furnish the brains and the labor but a large part of the money for the investigations which result in the utilities that all enjoy. One could name leaders in all branches of knowledge who piece out the living expenses of their families by pitiful outside jobs in order to be able to carry on their God-given tasks, when they might use their exceptional ability and knowledge like others to obtain princely incomes in the commercial world.

If any of our research institutions deserves public benefactions, most of all it is the national Smithsonian Institution. Founded by an Englishman, James Smithson, "for the increase and diffusion of knowledge among men," it has been the parent of the Weather Bureau, the Fish Commission, the National Museum, the Bureau of American Ethnology, the Geological Survey, the National Zoological Park, the Astrophysical Observatory, the Bureau of International Exchanges (of scientific intelligence), and the National Gallery of Art; has contributed largely to the Library of Congress; and has had a part in many other valuable enterprises. In its reports and technical papers the inquirer may find in accurate form, sometimes popularly, sometimes technically expressed, the whole progress of human knowledge. Not only that, but in a daily correspondence which taxes its small force of experts and clerks, it has answered millions of inquiries for useful or technical information. Though some of the bureaus just named have split away from the parent organization, the Institution is still charged by Congress with the care of eight of them. These administrative duties employ much time of the staff and in some measure prevent the promotion of projects for the advancement of science.

But, really, the Smithsonian Institution can not take a leading place in scientific research any longer because of its poverty. The present income from the endowment is only about $70,000 per annum. The Carnegie Institution and the Rockefeller Foundation each have more income than this every fortnight, and several other research institutions are almost in their class. Salaries at the Smithsonian Institution are on the scale of the year 1880. Young investigators of promise can not be secured to supplement and succeed those grown gray in service. No large projects can be undertaken. Even publication is restricted.

Surely if this were known generally a feeling of national pride would refuse to permit this great Institution associated with the researches of its famous secretaries, Joseph Henry, Spencer F. Baird, Samuel P. Langley, and Charles D. Walcott, to continue to languish.

Research has enhanced the Nation's strength and glory. Let it be fostered as it deserves. People of great wealth may do this in a large way without strain, and yet provide liberally for their heirs. Or great numbers of people of moderate means may share the enterprise, in full confidence that the outcome will help the world of the future to a richer life.

What would the Smithsonian Institution do if it had a large endowment?

1. Draw to itself the wisest counselors, and fix, with their concurrence, on the most needful projects, not being worked by others, and manageable with its endowment.

2. Pay sufficient salaries to its staff so that it could justly command all their time.

3. Procure young investigators of promise.

4. Broaden its output of publication.

If an illustration of what this might accomplish is demanded, consider the record of the Carnegie Institution. Founded 20 years ago, it set up eight principal projects, namely: The Mount Wilson Solar Observatory; the Department of Meridian Astrometry; the Department of Terrestrial Magnetism; the Geophysical Laboratory; the Laboratory of Experimental Evolution; the Marine Biological Laboratory at Tortugas; the Desert Botanical Laboratory at Tucson; the Nutrition Laboratory at Boston. In each case the director was a man with a passionate zeal for his job, and a sound program for its accomplishment. Subordinates hardly less zealous and competent were employed. The results have been so rich that if the accomplishments and the very remembrance of the work of these eight Carnegie Institution departments were now to be blotted out, our total knowledge of astronomy would be cut in half, the magnetic charts of the sea would be unfit for navigation, the United States Army and Navy would have wanted unobtainable essentials in the World War, sociology, biology, botany, and the science of nutrition would have lacked many of their most valuable data. Besides this there has been in these 20 years a rich flow of publications too costly for the private publisher to undertake, and many great pieces of research by exceptional investigators outside the Institution have been subsidized. Such is the record of a well-endowed research institution. Such ought to be made possible as the record for the next 20 years of the national Smithsonian Institution.

RECENT DISCOVERIES AND THEORIES RELATING TO THE STRUCTURE OF MATTER.[1]

By Karl Taylor Compton,

Professor of Physics in Princeton University.

Molecules of matter are sometimes defined as the smallest subdivisions which have the properties of the matter which they compose. Their existence has long been accepted because of the satisfactory explanation which they give of elastic, thermal, and other properties of matter, particularly in the gaseous state. More recently the existence of such particles in rapid random motion has been made almost visible in that we can accurately explain, by the bombardment of such molecules, the erratic, jerky movements made by a small particle immersed in a gas or liquid and observed through a microscope.

Atoms are sometimes defined as the smallest particles which take part in chemical reactions, and a chemical reaction is simply a change from one to another kind of grouping made by atoms of the same or of different kinds. Any characteristic grouping of atoms constitutes a molecule. The existence of atoms was first suggested to explain the fact of chemical combination of substances in definite proportions.

Within the last 25 years, and chiefly within the last 10 years, definite proof of the existence of atoms and molecules has been found and methods have been developed to count and weigh them *individually*, with very significant results. More important still, it has been shown that all atoms are themselves built out of still smaller and more fundamental units of matter, electrically charged, called positive electrons and negative electrons. There is very decisive evidence of the existence of these two fundamental types of matter and of the number of each type in any given kind of atom. To this extent the "electron theory of matter" is no longer to be considered

[1] Reprinted by permission from Princeton Lectures, No. 10, Princeton University, Princeton, N. J., June, 1922.

as a theory but as a fact. But when we attempt to explain *all* the physical and chemical properties of matter as due to these electrons and the electromagnetic forces between them we encounter some surprising and unexpected facts regarding the behavior of electrons when influenced by other electrons or by radiation, so that this is still a field of hypothesis and experimentation.

NEGATIVE AND POSITIVE ELECTRONS.

Properties of the negative electron.—When an electric discharge at several thousand volts is passed between two metallic electrodes sealed into a glass vessel from which most of the air or other gas has been pumped, the remaining gas and the walls of the glass vessel become luminous. This luminosity is of different sorts in different parts of the vessel and can easily be shown to be due to two different agents. One of these consists of something shooting out from the cathode, or negative electrode, and producing luminosity in everything in its path. The other consists of something shooting out from the anode and moving toward the cathode, also producing luminosity of gas molecules or other objects in its path, but luminosity of a different color from that produced by the stream from the cathode.

The so-called cathode rays are found to consist of a stream of negatively charged particles, as is proved by the fact that their paths are bent if placed in an electric or magnetic field, or by the fact that if they are caught in a metallic cup, this cup receives a charge of negative electricity. From the amount of bending in electric and magnetic fields of known strength, which may be seen by the luminous trace of the path of the stream along a properly placed fluorescent plate, it is possible to calculate the speed of the particles and the ratio of their charge to their mass, denoted by e/m. The speed of the particles depends upon the voltage applied to the discharge tube, but the value of e/m does not depend on the voltage or the kind of gas in the vessel or the material of the electrodes. It is a definite constant about 1,846 times larger than the ratio of the charge to the mass of hydrogen ions liberated by electrolysis. Thus, if the charge on one of these particles is equal to the charge on a hydrogen ion (as we shall see is the case), then these particles must be 1,846 times lighter than hydrogen atoms. These particles, which constitute the cathode rays, are the negative electrons. They may be driven out of metals by raising the temperature or by exposing to ultra-violet light or X rays, or by intense bombardment, or by chemical actions, etc. Their properties, as regards mass and charge, are the same however they are liberated and they must be considered as one of the fundamental units of which matter is composed.

The anode rays are also deflected by magnetic and electric fields in a direction showing that they are positively charged particles and by an amount showing that the ratio of their charge to mass is characteristic of atoms or molecules of the gas in the tube. In other words, they are the residues of the gas atoms or molecules which remain after electrons have been driven out. Knowing their charges, the bending of their paths in magnetic and electric fields enables their masses to be determined. It is in this manner that atoms and molecules have been *individually* weighed with high precision.

In order to find the mass m from the above values of e/m, it is necessary to know the charge e of a negative electron. This has been measured with the greatest accuracy by Professor Millikan about eight years ago. The most sensitive instrument for measurement of electric charges is the electroscope, which consists, essentially, of a strip of gold leaf suspended between two oppositely charged metal plates. When the gold leaf is charged it is attracted by one plate and repelled by the other, and the size of its charge may be measured by observing the distance which it moves from its uncharged position. But this instrument is not sensitive enough to measure the charge of an electron. Professor Millikan substituted for the gold leaf a tiny droplet of oil from the spray of an atomizer. Because of its weight it tended to fall through the air slowly, because of its small size and the viscous resistance offered by the air; but if this droplet were electrically charged, it could be drawn upward, in opposition to gravity, by an electric field between the two horizontal metal plates between which the droplet moved. By observing through a telescope the rate at which the drop fell in the absence of an electric field and the rate at which it rose in the field, data were obtained permitting a calculation of the amount of electric charge on the drop. It was found that all charges were simple multiples of a fundamental unit charge, which is the charge of an electron. Thus the negative electron is not only a fundamental unit of matter but also a fundamental unit of electricity.

By such experiments it is found that the mass of a negative electron is $8.97(10)^{-28}$ grams and its charge is $4.774(10)^{-10}$ electrostatic units. The mass of a hydrogen atom is $1.65(10)^{-24}$ grams.

Positive electrons.—When the positively charged residue of an atom, the part left after the loss of an electron, is weighed by measuring the bending of its path in an electric and magnetic field, two very significant results are obtained. In the first place, the weight of every atom, except hydrogen, is an exact integral multiple of the weight of a fundamental unit. This unit is one-fourth the weight of a helium atom, or one-twelfth that of a carbon atom, or one-sixteenth that of an oxygen atom, etc. The unit has *almost* the weight of a hydrogen atom, but is less by 0.77%. This discrep-

ancy is accounted for by the fact, discussed later, that when electrically charged particles are grouped together their combined mass differs slightly from the sum of their separate masses. We may conclude, therefore, that all atoms are built up of hydrogen atoms. We shall see later that the hydrogen atom itself consists of one *negative* electron and the part that remains, which is called the *positive* electron. The positive electron carries an electric charge equal to that of a negative electron, but of opposite sign, and is 1,846 times heavier. Thus we go a step further and conclude that all atoms are built up of positive and negative electrons.

Why was not this simple integral relationship between atomic weights discovered long ago, since chemists have accurately known atomic weights for many years? Simply because chemical methods of determining atomic weights measure only the *average* weight of a great number of atoms, but the method described above measures the weights of *individual* atoms. In the case of the element chlorine, for instance, the chemical determinations give the weight equal to 35.46 times our unit, but the deflection method shows that there are three different kinds of chlorine atoms, of weights exactly 35, 37, and 39, which are chemically inseparable and which are present in such relative proportions as to make the average atomic weight 35.46. These different kinds of chemically similar atoms, with different masses, are called *isotopes*. It has been found that isotopes exist in a large number of the chemical elements, but that the weight of every individual atom or isotope is an exact multiple of that of the fundamental unit.

If positive electrons, or the massive part of hydrogen atoms, are parts of the structure of all atoms, we might expect to be able to break up heavier atoms into hydrogen. This has actually been done by Professor Rutherford in the case of nitrogen, aluminium, and a number of other elements.

HOW ELECTRONS ARE ARRANGED IN ATOMS.

Thus we have both direct and indirect evidence that atoms are structures built out of positive and negative electrons. The next question is, "How are these electrons arranged in the various atoms?" A good deal is known about this arrangement, as I shall proceed to indicate, but there is much more which is still unknown.

The nuclear structure of atoms.—Radium and the other radioactive elements owe their unusual properties to the fact that they emit positively and negatively charged particles, called α and β particles, respectively, with tremendous velocities. By the bending of their paths in electric and magnetic fields, or by other methods, it is found that the β particles are negative electrons which have velocities as large as 97 per cent of the velocity of light, or about 180,000

miles per second. Similarly, the α particles are atoms of helium which have lost two negative electrons and which consist, therefore, of four positive and two negative electrons, forming a very compact and stable group. These have velocities as large as about one-tenth that of light. The β particles set up oscillations of negative electrons in neighboring atoms which they strike, and these oscillations produce radiation called γ radiation or wave motion in the ether. The atoms of radium do not "explode" in this manner frequently. In fact, the occurrence is so rare that the chances are even that any given atom will or will not explode within a time of 2,000 years. When it does explode there remains not an atom of radium (atomic weight 226), but an atom of radium emanation (atomic weight 222) and an α particle (helium, atomic weight 4).

In spite of their smaller velocity, the α particles possess much greater kinetic energy than do the β particles, being nearly 7,400 times heavier. It was by means of bombardment of nitrogen and other atoms by these α particles that Professor Rutherford has effected their atomic disintegration, yielding hydrogen as a product.

When the α particles shoot out through a gas, such as air, their paths may be seen and photographed, provided the air is saturated with water vapor and suddenly cooled by expansion. The air molecules in the path of the α particles have negative electrons forced out of them by the action of the positively charged α particle as it comes very close. These positively and negatively charged residues of the air molecules serve as nuclei for the condensation of water vapor. Thus the path of the α particle is visible as a thin line of water droplets. In air at atmospheric pressure these paths may be as long as 11 centimeters.

Now, the diameters of air molecules are known to be about $3(10)^{-8}$ cm., and there are about $2.7(10)^{19}$ of them in each cubic centimeter. An α particle, in traversing 11 cm. of air, would pass through about 200,000 molecules. Yet many α particles go this entire distance without changing the direction of their motion, and most of them go at least several centimeters without swerving from their course. This can only mean that *an α particle may pass right through thousands of atoms without colliding with that part of an atom in which practically all of its mass is situated.* We must, therefore, think of all of the positive electrons (and possibly some of the negative electrons) of an atom as grouped within a region which is excessively small as compared with the size of the atom. Around this compact group, or "nucleus," the remaining negative electrons are situated at relatively large distances—distances comparable with the atomic radius.

With all the heavy positive electrons and only some of the negative electrons constituting this nucleus, it is evidently positively

charged. An α particle is also positively charged, with a known charge. Professor Rutherford suggested that a collision between them, indicated by a sharp bend in the path of the α particle as it passes through the air, may be due simply to the effect of the repulsive force between these two charges when they come very near together. Darwin calculated, on this hypothesis, the fraction of all the observed deflections of α particles, shooting through air or any other substance, which should be within any specified angular limits. When this calculation was compared with the experimental measurements of deflections through various angles, it was found that there was exact agreement only provided the force between the α particle and the nucleus is taken to vary inversely as the square of the distance between them, and provided the charge of the nucleus of the atom is taken equal (in electronic units) to its *atomic number*. The atomic number of an element is its order in the periodic table, i. e., 1 for hydrogen, 2 for helium, 3 for lithium, etc.,

This conclusion was verified by an entirely independent method. When a beam of X rays passes through substances, some of its energy is abstracted and sent out in all directions. The amount, character, and distribution of this scattered radiation have been exactly accounted for by ascribing the scattering to the action of the electrons outside the nuclei of the atoms. These electrons are accelerated by the electric forces in the X-ray beam, and, as a result of their acceleration, give rise to the scattered radiation. Sir J. J. Thomson calculated the proportion of the energy of an X-ray beam scattered by each negative electron in its path. Dividing the observed amount of scattering by this gives the number of negative electrons taking part in the scattering. Dividing this by the number of atoms gives the number of scattering electrons per atom, which is found equal to its atomic number. But the number of scattering electrons (electrons outside the nucleus) must obviously equal the positive charge of the nucleus, in electronic units, thus verifying the previous conclusions regarding the nuclear charges of atoms.

Finally, a relation between the atomic number of an element and the vibration frequency of the radiation constituting its X-ray spectrum was discovered by Moseley. It can be expressed rather accurately by saying that the square root of the frequency of any particular type of X-radiation is directly proportional to the atomic number of the radiating element. This has been satisfactorily accounted for only by supposing that the atomic number of an element is equal to the electronic charge on its nucleus, i. e., to the excess of positive over negative electrons in its nucleus.

Atomic constituents.—The foregoing evidence, and much additional evidence, leads to the conclusion that the various chemical elements have atoms constituted as shown in the following table,

which contains only a few examples. Those elements bracketed together are isotopes.

Element.	Atomic number.	Atomic weight.	+ Electrons in nucleus.	− Electrons in nucleus.	−Electrons outside nucleus.
Hydrogen	1	1.007	1	0	1
Helium	2	4	4	2	2
Lithium	3	6	6	3	3
		7	7	4	3
Boron	5	10	10	5	5
		11	11	6	5
Carbon	6	12	12	6	6
Nitrogen	7	14.01	14	7	7
Oxygen	8	16	16	8	8
Neon	10	20	20	10	10
		21	21	11	10
		22	22	12	10
Mercury	80	197	197	117	80
		198	198	118	80
		199	199	119	80
		200	200	120	80
		202	202	122	80
		204	204	124	80

Thus far we may go with considerable certainty in our picture of atomic structure. When we endeavor to learn *how these electrons are arranged*, both within and without the nucleus, we must base our conclusions on such evidence as we can get from the nature of the chemical (electromagnetic) forces between atoms, from the ways in which the atoms may be broken up or their parts set into vibration, producing light or other radiation, from their behavior in electric and magnetic fields, etc. To understand the structure fully, we should know all about the forces which hold the parts together. In this direction some progress has been made but certain phases of the problem are very perplexing.

ELECTRONS AND RADIATION.

Quantum theory.—Electromagnetic theory leads to the conclusion that radiation is produced when an electric charge is accelerated, and this conclusion has been amply verified. Yet it appears that, under some conditions, electrons are accelerated without producing radiation. Ordinary dynamical theory leads us to expect that a negative electron, rotating or oscillating about a center of force, might rotate in an orbit of any radius or oscillate with any amplitude under appropriate conditions. Yet it appears that only certain particular stable motions are possible, those which satisfy the condition $\int p\, dq = hs$, where p is the momentum of the electron, q is its distance from some reference point in its path, s is any integer such as 1, 2, 3, etc., and h is a universal constant, known as Planck's constant. We naturally think of radiant energy as being emitted con-

tinuously from its source and being absorbed continuously by material in its path, these emitting and absorbing agents being known to be electrons. Yet there is evidence that radiant energy is absorbed or emitted as if in discrete units equal to hn, where n is the frequency of vibration of the radiation.

Such considerations have given rise to the *quantum theory*, which has been remarkably successful as a statement of the conditions under which an electron will or will not radiate and of the conditions under which it may be in equilibrium in an atom. Little progress has, however, been made in explaining the quantum laws, and, until this is done, it will probably be impossible fully to understand the forces which hold the parts of atoms together.

Spectral series.—In the apparently complicated spectra of chemical elements, some of which contain hundreds of bright lines in the visible spectrum alone, there have been discovered remarkable relationships between the frequencies of vibration of the different spectral lines of an element and between corresponding lines of different elements. These relationships may be expressed by *series formulae*, of which the following formula for the vibration frequencies of the various kinds of light, or spectral lines, due to hydrogen atoms is an example:

$$n = N\left(\frac{1}{r^2} - \frac{1}{m^2}\right)$$

Here n is the number of vibrations per section, N is a universal constant $3.29025(10)^{15}$ and r and m are integers which may have any value between 1 and infinity. Thus, if $r = 1$ and $m = 2, 3, 4, \ldots$, each value of m gives a frequency corresponding to a spectral line in the extreme ultraviolet. These lines constitute a spectral series. Similarly if $r = 2$ and $m = 3, 4, 5$, etc., we get a series of lines in the visible and near ultraviolet spectrum. If $r = 3$ and $m = 4, 5, 6$, etc., we get a series of lines in the infra red. The frequencies of these lines agree with the measured frequencies with an accuracy of about one part in a hundred thousand.

For elements other than hydrogen, there are added to r and m certain constants characteristic of the element, but r and m still take various integral values.

A study of the absorption or refraction of light by a medium leads to the possibility of calculating the number of atoms in the absorbing substance which are, at any given instant, capable of emitting light of any given frequency. By such methods we learn that only a small fraction of the atoms are, at any instant, taking part in the emission of light and that *the atoms emitting one line in the spectrum are different from those emitting any other line.* Thus an atom, when it emits radiation, emits only one frequency of radiation at a time.

Zeeman effect.—Mention only can be made of the discovery by Zeeman in 1896 that, when a source of light is placed in a strong magnetic field, its spectral lines are split up into several components. The nature of this effect leads to the conclusion that light is emitted by negative electrons which, during emission, are moving in orbits which are usually circular, but sometimes elliptical. As a matter of fact it was the study of the Zeeman effect which first led to the discovery of the negative electron and to a determination of the ratio of its charge to its mass.

Radiation and atomic structure.—A constant correlation of the facts of radiation is obtained by supposing that there are only certain definite conditions in which a negative electron may exist in stable equilibrium in an atom, each of these conditions being characterized by a certain total energy (kinetic plus potential). In the case of hydrogen, for example, the energies of all these states are given by $-Nh/s^2$, where s may have any *integral* value and each such value specifies the energy of an electron in a particular state. When, for any reason, an electron passes from any state of energy W_m to a state of less energy W_r, the difference between the energies is sent out as radiant energy. Thus the energy radiated is $W_m - W_r = Nh\left(\frac{1}{r^2} - \frac{1}{m^2}\right)$. Combining this with the quantum law in form $W_m - W_r = hn$, we have, for the frequency of the resulting radiation, $n = N\left(\frac{1}{r^2} - \frac{1}{m^2}\right)$ which is the ordinary series formula for hydrogen. Similarly, for any element, we interpret the series formula, for any two integral values of r and m, as proportional to the difference between the energies of an electron in the two corresponding states, and take h to be the constant of proportionality. An electron may pass from any state to any other state. If the integer characterizing the second state is less than that characterizing the first, energy is radiated. If the second integer is greater than the first, energy is absorbed by the electron, from whatever agency produces the displacement.

This, in very bald outline, is the theory of spectral radiation and of those features of atomic structure which determine the nature of its radiation. When we attempt to account for or describe these particular stable states (which really involves accounting for the quantum laws) by any dynamical model of an atom, our steps become more uncertain, although some notable advances have been made.

ATOMIC MODELS.

The Bohr theory.—Bohr, followed by Sommerfeld and Silberstein, has formed atomic models which have been remarkably successful in accounting for the phenomena of radiation and ionization (or breaking up) of systems consisting of a positive nucleus and a single outer negative electron, but which have not been developed

successfully to account for these phenomena in more complicated systems, nor for the magnetic properties of atoms.

For the simplest case, a relatively heavy nucleus of positive charge E and a negative electron of charge e and mass m rotating n' times per second about the nucleus in a circular orbit of radius a, we have equilibrium if the electric attraction is just balanced by the centrifugal force, or

$$\frac{eE}{a^2} = (2\pi n')^2 a$$

The total energy, kinetic plus potential, is easily shown to be

$$W = -\tfrac{1}{2}\frac{eE}{a}.$$

By the quantum law $\int p\, dq = hs$ it is found that the only possible values of W are those for which $W = -\tfrac{1}{2}\, s\, h\, n'$, where s is any integer. By solving these three equations simultaneously we find the various possible energies and radii of the atom to be given by substituting the various integral values of s in the equations

$$W = -\frac{2\pi^2 me^2E^2}{s^2h^2}, \quad a = \frac{s^2h^2}{4\pi^2 meE}.$$

Since the difference of energy in any two states equals hn, the various possible radiation frequencies are given by $n = (W_m - W_r)/h$, or

$$n = \frac{2\pi^2 me^2E^2}{h^3}\left(\frac{1}{r^2} - \frac{1}{m^2}\right),$$

where r and m are any two integral values of s. E is simply the atomic number of the element times the electronic charge e.

These three equations are in exact accord with all experimental evidence available. The spectral tests of the latter equation are particularly severe and convincing, since substitution of the known values of the constants makes the term outside the parenthesis exactly equal to the observed Rydberg constant N, so that the equation is identical with the spectral series formula.

This theory has been extended to take account of the small motion of the nucleus as the electron revolves, of possible elliptic as well as circular orbits, of the variation of the mass of an electron with its speed and of the effect of placing the atom in a strong electric field. In every case the theory leads to results in *exact* accord with the facts. When dealing with systems with several negative electrons outside the nucleus, the problem of the way in which they and their orbits are distributed in space must be considered. Models with coplanar, parallel and crossed orbits have been considered, with the latter giving, on the whole, the best results. But the computations are very complicated, and but little progress has been made with such systems or with molecules.

The Lewis-Langmuir theory.—In marked contrast with the preceding *dynamical* model of an atom, Professor Lewis and Doctor Langmuir have developed a *static* theory of atomic structure to account, primarily, for the chemical valencies of atoms and the periodic recurrence of their properties when they are arranged in the order of their atomic numbers. In this theory the electrons outside the nucleus are arranged as symmetrically as possible in positions on the surfaces of imaginary concentric "shells." The maximum possible numbers of electrons in these are 2 in the inmost shell, 8 in the next, 8 in the next, 18 in the next, 18 in the next, etc. No shell can contain any electrons unless all the shells inside it contain their full quota of electrons. The number of electrons to be thus distributed in the case of any given atom is equal to the atomic number of the atom. Chemical combinations of atoms are supposed to be due to the "sharing" of electrons in common by different atoms in such a way as to give the outer shells of all the atoms as nearly as possible their full quota of electrons. This theory of chemical combination, which we have, of necessity, treated very inadequately, is in more complete accord with the facts of combination than any other yet proposed.

Discussion.—The chief weaknesses of the Bohr theory are its failure to account easily for certain chemical properties and the uncertainties regarding its proper method of application to any but the simplest atoms. The weakness of the Lewis-Langmuir theory, on the other hand, lies in its qualitative rather than quantitative nature and its disregard of all questions of structural stability, radiation, and phenomena due to any part of the atom except the electrons in the outer shell. Yet the striking successes of both theories in particular fields suggest that both contain elements of truth. The present endeavor is, therefore, to reconcile the two viewpoints, and some progress in this line has been achieved.

MATTER, ELECTRICITY, AND ENERGY.

Whenever an electrically charged body is set in motion a magnetic field is set up in the region surrounding the body. But a magnetic field can not be produced without expending energy, and it is possible to calculate how much work must be done to set up any given magnetic field. Obviously, therefore, more work must be done to impart a given speed to a body when charged than if it were uncharged. In other words, the presence of the charge increases the inertia, or mass, of the body. The question immediately suggests itself, therefore, "Is *all* mass due simply to the electric charges of the positive and negative electrons of which matter is composed?" Certain experiments on the variation of the mass of a negative electron with its speed, at speeds approaching the velocity of light, indicate that *the mass of a negative electron is entirely due to its charge*, so that

it has no material mass as distinguished from electromagnetic mass. Therefore we consider a negative electron to be not a particle of matter bearing an electric charge, but simply a particle or unit of negative electricity.

It has not been possible to make similar experiments with positive electrons, but all we know about them points toward the conclusion that they also are simply units of positive electricity. It is believed, therefore, that matter, in its ordinary sense, is simply an aggregate of positive and negative electric charges.

Furthermore, the electromagnetic mass of any electric charge can be shown to be always proportional to the energy of the electric field to which it gives rise. It is unnecessary, therefore, to distinguish between mass and energy. Whenever the total electrical energy of a group of electrons changes by a change of their relative positions the mass of the group also changes in a definite proportion. Theoretically, therefore, all chemical combinations should result in a change of total mass. But the energy changes in chemical reactions correspond to mass changes which are too small for detection by the most sensitive instruments. In cases of atomic disintegration, such as in radioactivity, however, the energy changes are very large in comparison with the energy changes in chemical reaction, and suggest the possibility of detecting the corresponding mass changes. Sir Oliver Lodge has stated, as an example of radioactive energy, that if the total energy liberated during the disintegration of 1 gram of radium could be utilized for the purpose, it would suffice to lift the entire British Navy several thousand feet. These energy changes are large enough to suggest the possibility of showing that the mass of radium is greater than the total mass of the elements into which it splits up. Such measurements have not as yet been made, since radium splits up so slowly. We therefore combine two fundamental laws—the principle of the conservation of mass and the principle of the conservation of energy—into a single principle, that of the conservation of energy.

In this connection attention should be called to the probable reason for the slight excess in the atomic weight of hydrogen over that of the least common multiple of the other atoms. In the heavier atoms positive and negative electrons are packed together in the nucleus, so that their electric fields partially neutralize each other, thus diminishing the total energy and hence the total mass. If we suppose the universe to have been originally formed by the grouping together of positive and negative electrons, the energy liberated as they combine to diminish the total mass in the observed ratio 0.77% is sufficient to have accounted for the heat of the sun and stars for about a million million million years—an ample period to satisfy the most exacting geological and evolutionary theories.

THE ARCHITECTURE OF ATOMS AND A UNIVERSE BUILT OF ATOMS.

By C. G. Abbot.

In a lecture given by Dr. H. N. Russell at the Carnegie Institution in December, 1922, he concluded with this remarkable statement:

> If a first-rate physicist, well versed in all the knowledge acquired in the laboratory during the last quarter century on the structure and properties of the atom, should have lived his life on a planet so enshrouded by clouds that neither he nor others had ever glimpsed the starry heavens, yet if he had the imagination to conceive that immense quantities of matter might lie beyond the clouds, he would be able to picture the heavens much as they are, tell the probable maximum masses of the stars, their minimum distances, the range of their diameters and temperatures, the differences of their spectra, and in short to duplicate by prediction, not only in general features but in many of the finest details, the actual appearance of the universe forever hidden from him.

Let us run over some parts of the course which his mind might follow in this extraordinary prediction. First, what is an atom and how is it related to light?

The atoms of all substances are built of what we might call the same kinds of bricks. There are two kinds in every atom, one kind called protons, which are positive electrical charges, and the other called electrons, which are negative electrical charges. Of these, all of the protons are clustered at the center or nucleus of the atom, but some of the electrons lie in outside orbits, or if not properly orbits then vibrating semistable configurations of definite radii as measured from the nucleus. It is not difficult to detach electrons from the atoms of many kinds of chemical elements. This can be done by heating, by electrical means, and by bombardment of radium or X rays. Sometimes the electrons pass in this manner only from one orbit or position of configuration to the next, but sometimes they are driven quite out of the sphere of influence of their atom, become temporarily free electrons, and are captured by some other atom after wandering free for a brief time. In these separations and approaches of electrons from orbit to orbit reside the absorption and

production of light rays and of all such rays, including the infra-red, the visible, the ultra-violet, and the X rays.

The diameter of an atom—that is to say, the diameter of the sphere within which all the protons and electrons of a single atom find themselves—does not exceed one ten-millionth part of the diameter of an ordinary bird shot. Hence a single atom is quite too small to see even with a microscope. Moreover, an atom, as we have remarked, is not solid, but itself composed of a number of particles—the protons and electrons—well separated. Indeed, these constituents of the atom are excessively small compared to what we have just described as the diameter of an atom. A single electron is only one fifty-thousandth part of the diameter of an atom. Comparing this to one of the planets, the diameter of Mars bears roughly the same ratio to the diameter of its orbit that holds between an electron and an atom. Similarly the nucleus of a heavy atom, like that of lead, containing many protons and electrons, bears somewhat the same proportion to the whole atomic volume that our sun, 865,000 miles in diameter, bears to a sphere just inclosing the orbit of the planet Jupiter. From these figures we see that the inclosure we call an atom is almost wholly given up to free space. The occupied parts form hardly any greater volume, proportionally, than the sun and planets do to the solar system.

Matter exists in the three states—solid, liquid, and gaseous. The two former have densities that are nearly equal. For instance, water is of about twice the density of ice. But gases are of all densities, from that of their liquids to as little as one pleases, depending on the pressure one applies to keep them so. What, then, are the distances apart of the several atoms of a solid? This is known for many crystals by experiments with X rays. In common salt, for example, the distances are of only two or three times the magnitude as given above for the diameter of an atom. Such, then, are the distances between the nuclei of the atoms for solids and liquids, and from this up to *anything* greater for gases, depending on the pressure. In solids, and to a less extent in liquids, the atoms are so far restricted by their mutual proximity and interacting forces of attraction and repulsion that there is no wandering, or but little, of the atoms through the mass, so long as new forces are not introduced. Individual electrons, freed from atoms temporarily, may easily travel along under the urging of electric field, difference of temperature, or bombardment by radium or X rays. In gases, however, especially very rare gases, as in a vacuum, the whole atoms, or the combinations of atoms called molecules, fly about over relatively long paths before hitting each other, and so are continually remixing within the gaseous volume.

The forces which define atomic positions, orbits, or spheres of influence, are electrical attraction and repulsion, and electromagnetic effects of electric charges in motion. A neutral atom, which has neither furnished free electrons nor captured any, has a definite number of orbital electrons, each with its unit electrical negative charge, and in the nucleus an excess of protons over bound electrons sufficient to make up for the nucleus the same electrical charge as carried by orbital electrons, but positive. Although the electrical charges of electrons and protons are equal and opposite, the masses of the two primitives are greatly unequal. An electron has only about one two-thousandth part the mass of a proton. Yet the protons are not on that account larger than the electrons in dimensions, only exceedingly more massive.

All the usual physical and chemical properties are definitely fixed when the excess positive charge of the nucleus is given. The excess of positive charge on the nucleus may be gotten in two ways, either by adding protons or subtracting electrons from it. To subtract electrons scarcely alters appreciably the weight of the atom (atomic weight). But to change the number of protons does essentially alter the atomic weight. Hence it is that two dissimilar chemicals may have about equal atomic weights, for example, bismuth and thorium-lead each 208; while thorium-lead and uranium-lead, for example, which are both quite indistinguishable from each other or from ordinary lead (207.20) have atomic weights 208 and 206, respectively. Readers of the Smithsonian Report for 1919 will remember Doctor Aston's brilliant work along these lines, and further back in the report for 1918 Doctor Richards's telling work on the atomic weight of lead.

We are apt to think of solids ordinarily as completely occupying the spaces inclosed by their boundaries. Recent knowledge shows how radically this notion must be changed. For the protons and electrons, which alone can be regarded as really occupying space, are certainly more like the motes which dance in the sunbeam in a room full of air, than like a structure completely occupying the same volume. This shows us how it is possible for metallic wires to conduct electricity. It is the electrons which, flying through the free spaces within and between the atoms, are the conducting agents. And yet an electron does not have to travel clear along the entire length of the wire to give the impression of an electric current. For at the positive pole free electrons will be attracted, thus making a void of them there, and tending to neutralize the positive pole, while at the negative pole they will be repelled, making an excess there and tending to neutralize the negative pole. Adjacent regions of

wire will supply the void and take up the excess as long as these inequalities remain, just as air molecules rush along to equalize pressure differences. So it is that as water buckets at a country fire are passed from hand to hand, the electric current does not require to be conveyed by original electrons all the way through the wire from the negative pole to the positive pole.

But some one may ask: "If the solid bar I push my top window shut with is no more than a flimsy structure of flying motes, how can it transmit pressure?" The forces of electrical attraction and repulsion retain to the bar its form, and, somewhat as a steam or air riveting hammer can be operated by a medium made up of particles well separated, so pressure can be transmitted by a bar made up of protons and electrons.

Without pursuing this résumé of atomic science further at the moment, let us turn to some aspects of the stars.

As regards their intrinsic brightness, the stars are now classed as the giants and the dwarfs. Giants are stars which are many times, even thousands of times, more luminous than the sun. Dwarfs are stars which range from near the brightness of the sun to complete extinction into cold nonluminosity like that of the earth. As regards their color and the details of their spectra, 99 per cent of the stars are assigned according to the universally accepted Harvard classification in six principal types, called by the letters B, A, F, G, K, M. Originally all the letters of the alphabet from A to M were used, but it was found presently that the classes assigned to other letters were unnecessary and only those above named were retained. Moreover, in the rational order of development of spectrum characteristics, class B appeared to precede class A, hence the irregular order as given above is now always followed.

There is a very extraordinary march of change of density associated with these star classes. The giant red star α Orionis (Betelgeuse), of spectrum type M, recently measured at Mount Wilson, is 300 times the diameter of our sun and not more than a thousandth part as dense as the air of the room. Our sun, a dwarf of type G, is 1.4 times as dense as water. Barnard's "runaway star," a dwarf of type M, is probably nearly as dense as the earth. This leads us up to the view which astronomers now generally hold as to the evolution of stars. Beginning to glow as rare gaseous giants of type M, showing in their spectra the lines and bands of the metals and compounds of them, they grow denser and hotter as time goes on, apparently simplifying in spectra. First, the bands due to compounds fall out, for, as we well know, high temperatures break up

all chemical compounds into atoms, then the metallic spectrum lines grow faint, with hydrogen lines becoming strong, and at length in the blue-white giant stage of Rigel and Spica, where maximum temperature is reached, only hydrogen and helium lines remain. This is the turning point. The star cools and grows denser as it goes on into the dwarf stage. Metallic lines reappear, and at last the star fades out as a dwarf of type M, now indistinguishable in spectrum, except for certain details visible only to experts (which, nevertheless, are highly characteristic of the altered density), from its original type as a class M giant. This progress is summarized in the following table:

Life history of a star.

Condition.	As a giant star.						As a dwarf star.					Later stage.
Harvard spectrum class.	M	K	G	F	A	B	A	F	G	K	M	.....
Color.....	Deep red...	Orange.....	Yellow.....	Light yellow	White....	Bluish white.	White....	Light yellow	Yellow.....	Orange.....	Deep red...	Dark.
Prevailing chemical elements of spectrum.	Banded spectra of metallic oxides.	Metals strong; very weak bands.	Many metals; no compounds.	Metals faint; hydrogen.	Hydrogen	Hydrogen; helium predominates.	Hydrogen	Metals faint; hydrogen.	Many metals; no compounds.	Metals strong; very weak bands.	Banded spectra of metallic oxides.	Water-carbon dioxide.
Typical star.....	Betelgeuse.	Arcturus.....	Capella.....	Canopus....	Vega.....	Spica.....	Altair....	Procyon.....	Sun.....	Groombridge, 1618.	Barnard's "runaway" star.	Earth.
Temperature....	3,000° C.	4,000° C.	5,500° C.	7,000° C.	9,500° C.	12,000° C.	9,500° C.	7,500° C.	6,000° C.	4,500° C.	3,000° C.	20° C.
Density compared to water.	0.0000005	0.0001	0.001	0.01	0.05	0.1	0.3	0.8	1.4	2.0	4.0	5.5

These data are not to be taken too rigidly, but rather to give a general picture of stellar evolution.

The great question which this table raises is this: If a star actually passes through the states enumerated, why do the spectrum lines of the metals disappear as the star approaches its culmination as a blue-white giant and then reappear at a later stage as a yellowish dwarf? Can we believe that the mere exaltation of temperature destroys the metals, resolving them into the simpler atoms of hydrogen and helium? Such a view at first sight seems reasonable, in view of the now well-known fact that some of the heavy metals—uranium, thorium, and radium—continually break down spontaneously with formation of helium, and that Rutherford and Chadwick have indeed disintegrated the lighter elements—nitrogen, boron, fluorine, sodium, and phosphorus—with expulsion of hydrogen. But the proportion of the atoms affected was only trifling and the means employed for knocking out the protons from the atomic nuclei were the alpha rays of radium, means as powerful as would be the maintenance of a temperature of millions of degrees, perhaps a thousand times as powerful as the effects of the actual temperatures at the surface of the blue stars. Accordingly, we must regretfully give up this simple temperature explanation of the disappearance of the metals from the spectra of the hotter stars. It demands temperatures higher than the stars afford, for measurements already made limit us there to surface temperatures not exceeding 20,000° C.

What appears to be the main factor in the true explanation is simpler still in essence, though involving such intricate and obscure properties of the structure of the atoms as not yet to be fully worked out by physicists, at least in the cases of any but the simplest of atoms. In short, rise of temperature, or, speaking more broadly, increased intensity of excitation, alters the atoms by setting free electrons in such a way that the spectrum lines given out shift over from the visible and photographic regions of the spectrum to those of shorter wave length beyond the violet, where the earth's atmosphere is not transparent to them. Thus the metallic spectra are still present even in the hottest stars, but are merely removed from the familiar spectrum region, where they can be observed, to another where they can not penetrate our atmosphere.[1]

This behavior of the spectrum lines of the elements is illustrated by laboratory work and explained by theoretical researches of Bohr, Saha, and others on the relations of atomic structure to spectra. Laboratory spectra are of three principal kinds, called flame, arc, and spark spectra, according as they are excited by sources like low temperature flames, the higher excitation of the electric arc, or the still more intense action of the electric spark forced by high electrical potential differences and often reenforced by condenser dis-

[1] There is another factor which we shall touch upon later.

charges. In flame spectra certain lines and bands of an element are conspicuous, but these are comparatively few, and many others are faint or lacking. In the arc the flame lines remain, but the emphasis may fall on quite different individual lines. Many more spectrum lines make their appearance. Again, in the spark still another rearrangement of intensities appears. Prominent flame and arc lines grow faint and new lines are found. Thus differences in spectra of the same chemical element which are produced experimentally depend on the degree of excitation.

According to Bohr's theory of the atom, when an orbital electron is driven from its neutral position by the excitation of high temperature or electrical discharge, it may migrate to one or another of certain orbits, determined by limitations, depending on Planck's theory of the so-called "quantum," that unit of energy which crops up so widely in physics, as readers of Millikan's article in this report for 1918 are aware. In each of these possible orbits the electron has a definite energy. Returning to its normal place from one of these excursions, the electron from an outer to an inner orbit gives up the difference between the definite energies appropriate to the two situations and thereby gives rise to radiation in a specific spectrum line. If the electron temporarily occupies successively several orbits during its return, several spectrum lines are formed corresponding in the frequency of their vibrations to the several definite differences of energy involved. The actual spectrum at a given instant is the joint result of all the electronic excursions of all the atoms involved.

The difference between arc spectra and spark spectra is explained as follows: In arc spectra the lines are supposed to be produced by the migrations of single electrons displaced from each of the partaking atoms. In spark spectra two electrons may be removed, one to a great distance. This one is that which took part in arc spectrum phenomena. It is assumed to be eliminated from the system. But the second electron in falling back to its position produces a similar series of spectrum effects, but involving different amounts of energy, and thus different frequencies of vibration for the lines produced. These new spectrum lines are then associated with the *second* displaced electron and with the *twice-shorn* remainder of the atomic structure. As the new energies involved greatly exceed the old, the frequencies of vibration are correspondingly enhanced, so that on the whole the new lines lie toward the violet of the old, and may even lie beyond the region of experimentation.

Complicated and hypothetical as all this may seem with so inadequate a presentation as the above, yet remarkable predictions have been made thereby which were later experimentally verified with

most striking success. Unfortunately the mathematical analysis becomes hopelessly involved for elements of high atomic weight, so that such verifications are confined so far to the simpler atoms, such as hydrogen, helium, and some of the alkalis.

Bohr's atomic theory received complementary contributions useful for explaining the spectra of the stars from considerations advanced by Saha. He points out that within the range of temperatures and pressures (hardly less important than temperatures) prevailing in the gases at the surface of a given star, the different elements will be ionized in different degrees, depending on their characteristic "ionization potentials," some of which have been measured in the laboratory. Also that the numbers of neutral atoms, atoms less one electron, atoms less two electrons, etc., are (in principle at least, if not yet in actual fact) calculable thermodynamically from energy considerations connected with the ionization potentials, the temperatures and the pressures prevailing. Proceeding to illustrate with assumed numbers for the element calcium, he shows that as between temperatures of 2,000° and 4,000°, absolute centigrade, the relative strength of lines corresponding respectively to neutral, once-shorn, and twice-shorn atoms must have altered immensely in favor of the latter, and so at the higher temperature the line spectrum of calcium will have gone over predominantly into a region of shorter wave lengths. Moreover, as the permanent gases, hydrogen, helium, and others, have greatly higher "ionization potentials" than elements like sodium, calcium, and others, the stimulation will at first pass by preference to the easily excitable atoms of the latter in cases of mixture of elements like that prevailing in the sun and stars. But as the easily ionizable elements become fully ionized, and, with the loss of one or even two or more electrons, become greatly more difficultly excitable, the stimulus of the temperature will more and more be diverted to affect difficultly ionizable gases like hydrogen and helium.

Hence, from two directions the spectra are influenced to alter as the star temperature waxes greater. First the dissociation of the atoms of the metals tends to throw the intensity of metallic spectra more and more into the ultraviolet regions which lie beyond our observation owing to the absorption in our atmosphere. Second, the increased difficulty of exciting these once-shorn or twice-shorn metallic atoms throws the effects of the temperature stimuli more and more to intensify the lines of the difficultly ionizable hydrogen and helium. Finally, the less conspicuous but highly significant and experimentally valuable influences of changes of pressure associated with the march of stellar evolution find equally satisfactory theoretical explanations. All of this is wholly in accord with the observations of

the spectra of the sun and stars, and many of the details which have heretofore been among the apparently insoluble puzzles of celestial spectroscopy are becoming clear in the light of Saha's expositions. These cover not merely emission but absorption of light in the most striking manner. If it were possible to express these in language easily to be understood, the reader would join in the wave of enthusiasm which is just sweeping through the workers in astronomical spectroscopy and kindred lines as they see the great problems of stellar evolution yielding to laboratory experiment and penetrating theory.

AERONAUTIC RESEARCH.[1]

By Joseph S. Ames, Ph. D., LL. D.

Professor of Physics, The Johns Hopkins University, Baltimore, Maryland; Chairman, Executive Committee, National Advisory Committee for Aeronautics.

[With 5 plates.]

Progress in the navigation of the air is being made constantly along two quite distinct and independent lines; one is the art of flying and the other is the science of flight. To this last is given the name aeronautics; and by an aeronautical investigation is meant a research which has a direct bearing upon our knowledge of the properties of solid bodies immersed in a stream of air or moving through the air. We wish to know the forces and moments acting upon such solid bodies; how these vary with the shape and characteristics of the bodies, and how they are affected if the velocity of the air is changed. Another important inquiry refers to the stability of the solid body when in flight; if the attitude of the body is changed by some gust or otherwise, does it tend to return to its previous attitude, or on the contrary does it continue to depart more and more from its original attitude? The question is like that referring to a body balanced on a table. If it is pushed slightly, will it simply oscillate to and fro, or will it turn over? These matters and similar ones make up the subject of aeronautics; and in order to investigate them the same methods must be applied as in any department of physics.

Experiments must be performed; a theory is evolved; deductions are made from the theory and tested by experiment; the theory is modified and improved, etc. During all the process knowledge is being gained, and the facts being made known help the designer of aircraft to make improvements in speed, in carrying power, in safety, in stability.

One most important fact should be emphasized, and this is that without the series of scientific studies just outlined not only would flight itself have been impossible, but also all progress in the art would

[1] Presented at the meeting of the Section of Physics and Chemistry of the Franklin Institute held Thursday, Oct. 6, 1921. Reprinted by permission from the Journal of the Franklin Institute, January, 1922.

cease. Scientific investigation forms the most important feature of aviation, and it can be conducted only by trained students. The best pilot in the world may know very little about the scientific principles underlying flight, and he would therefore be unable to make any marked improvements in his machine. Aeronautics is in no sense a function of an engineer or constructor or aviator, it is a branch of pure science. Those countries have developed the best airships and airplanes which have devoted the most thought, time and money to the underlying scientific studies. When the physical facts are known, the engineer can design his aircraft, the constructor can make it, and the trained man can fly it; but the foundation stone is the store of knowledge obtained by the scientist.

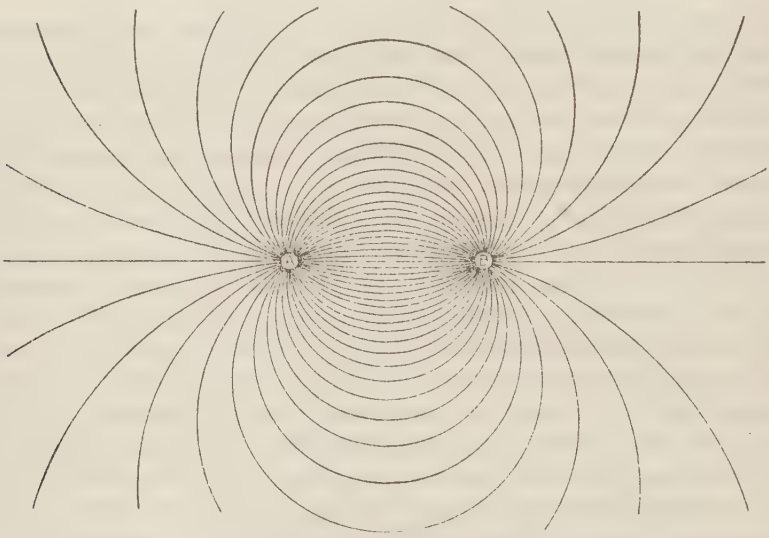


FIG. 1.—Combination of source and sink.

Before describing the types of investigations in progress in aeronautics and the methods pursued, it may be interesting to see some illustrations of the two types of aircraft now in use—the airship and the airplane. If I had time, I would like very much to say something about the helicopter, a type of aircraft to which we have given a name before constructing one. Up to the present no such machine, worthy of the name, has been made; but beyond a doubt one will be constructed, and in the near future.

An airship owes its flying power to the fact that it is made "lighter than air" by being filled with a gas lighter than air. Hydrogen is the gas always used, although helium may be. The lifting power of the latter gas is about four-fifths of that of hydrogen. As the airship moves through the air, it meets with

opposition as the air flows along its surface. Forces are required to move the control surfaces, *i. e.*, the rudders and elevators. We must determine these forces, and must investigate the changes in them as we change the shape of the airship, e. g., its length or its cross-section. A great deal may be learned by studying theoretically the way in which air flows around a solid body shaped more or less like an airship. A most interesting mode of attack on this problem was devised by Admiral Taylor of our Navy, and was applied by him to the design of ocean vessels. The drawings illustrate how a uniform flow superposed upon a source and sink produces a condition like the flow around an airship. This type

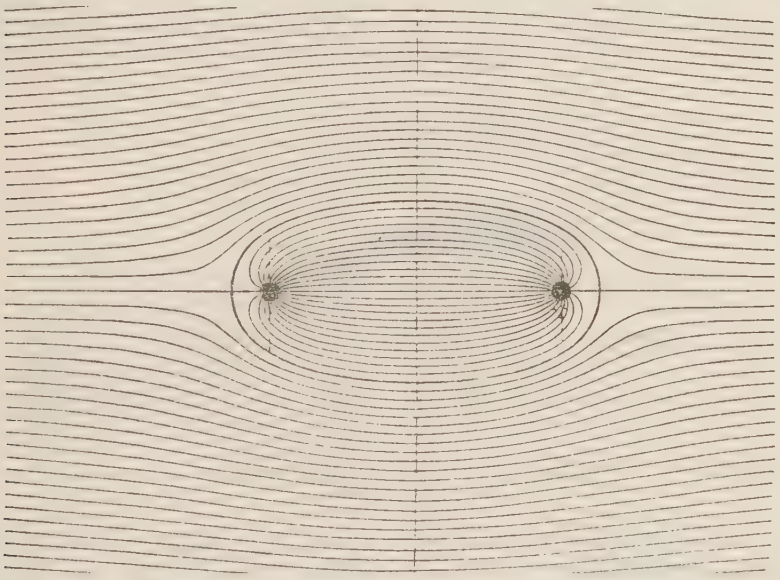


FIG. 2.—Air flow due to superposing a uniform rectilinear flow upon a combination of source and sink.

of flow may then be studied mathematically; the pressures may be deduced, etc.

Similarly, in the case of airplanes, we must know the character of airflow past the struts, the fuselage, and the wings. It is the difference in the pressure on the two sides of a wing that produces the upward force required to support the machine. The figures on plate 3 illustrate the type of flow around the aerofoil.

Great progress has been made in recent years by Prandtl and other German physicists by showing how a flow of air around an aerofoil could be produced in an ideal frictionless gas similar to that observed in air by imagining vortices or whirls in the gas. The method is not unlike that mentioned above as useful in the case of airships, only vortices are used in place of sources and sinks.

Following this process, Prandtl and his associates have shown how one could calculate the influence of one wing of a biplane upon the other, so that if the behavior of one wing is known that of two may be deduced; and they have proceeded much further and made aeronautics into a beautiful theoretical science.

But in the end the function of aeronautic research is obviously to learn all there is to be known about the forces acting on an aerofoil or wing. How can this be done? It is not possible to make actual airplanes of various types and test them, nor would this help us much if it were practicable. We must actually measure the forces involved in any one case, and must vary our conditions in every conceivable way, but in a systematic manner. There are several methods open to us. One is to make a model of a wing, say, as nearly full size as possible, suspend it by wires 30 feet or

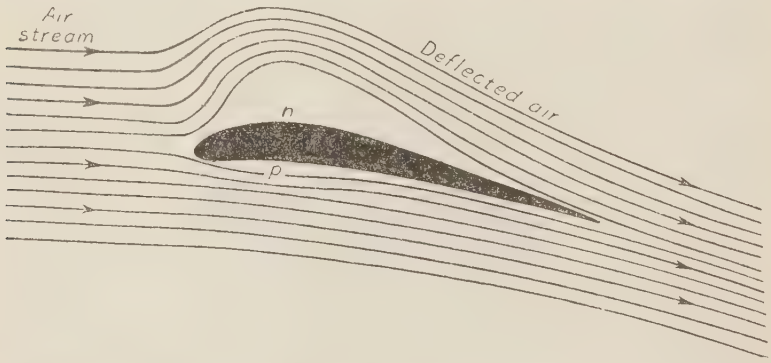


FIG. 3.—Diagram of flow past an aerofoil showing an increased pressure below and a decreased one above.

more below an airplane which can carry it in flight, and then, by inserting measuring instruments in the wires, study the forces under varying conditions. This method is being used with marked success at Langley Field, near Old Point Comfort, Va., by the staff of the National Advisory Committee for Aeronautics. It is called the "free-flight method."

A second method is to make a small model of a wing or a fuselage or an entire machine, say, one twenty-fifth the size of the actual part, and then to investigate the forces acting on it when it is placed in a rapidly moving stream of air. This is known as the wind-tunnel method, and is now in general use in all countries. England has 10 or more such tunnels, France has several, Germany has a large number, etc. In this country there are 12, and more are being made.

Other methods have been used in the past but are no longer. Langley attached his models to one end of a long arm which could

be made to revolve rapidly in a horizontal plane. Others have studied models of different shapes by dropping them from heights inside buildings, so as to avoid wind.

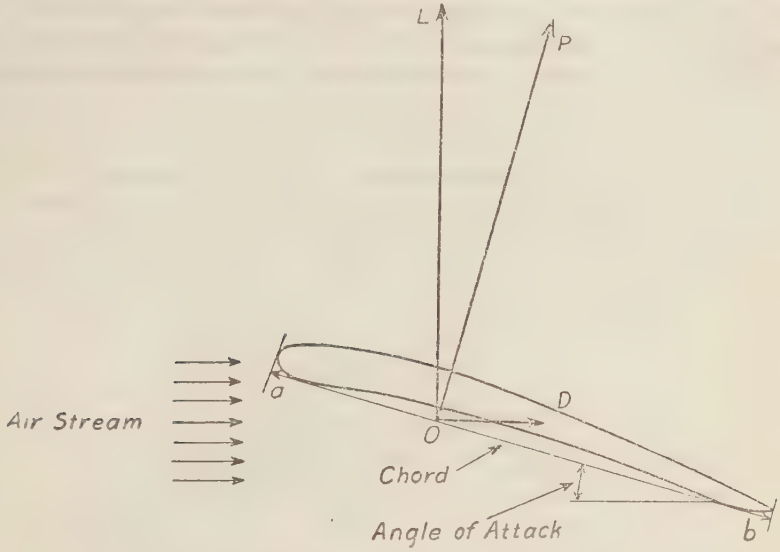


FIG. 4.—Diagram illustrating forces acting on an aerofoil.

Owing to the importance of wind tunnels, I have introduced plates 4 and 5, which show some photographs of the latest one made in this country, that of the National Advisory Committee for Aeronautics at the Langley Memorial Laboratory, Langley Field, Va.

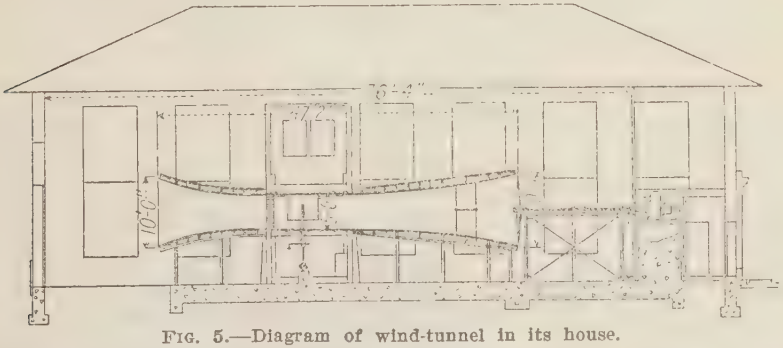


FIG. 5.—Diagram of wind-tunnel in its house.

Investigators in these different laboratories all over the world have studied the greatest variety of problems—forces on models of wings of different shapes at different air velocities, forces on models of airships, the effect of disturbing elements on these forces, etc. A long series of investigations has been made in particular upon air propellers. The blade of a propeller may be considered as made

up of a number of separate surfaces, and when the shaft is rotating each of these is thought of as an aerofoil moving rapidly through the air. In this way the action of a propeller may be calculated, and the theory may be tested by trying the actual propeller. But there is one all-important difficulty in applying the knowledge thus available to the design of actual aircraft. Is one justified in drawing

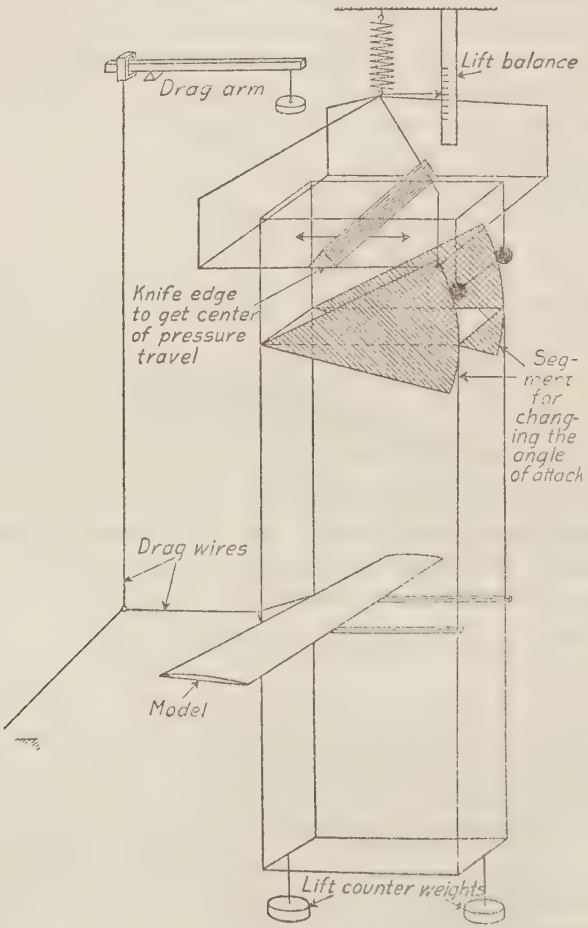


FIG. 6.—Scheme of the balance used to measure the forces on a model.

conclusions as to the properties of large bodies from knowledge of the properties of smaller ones? Suppose, for instance, that on comparing two models on a scale of one twenty-fifth of full size in a wind tunnel through which the velocity of the air stream is 40 miles per hour, it is found that one model has a greater lift or a less drag than the other, what conclusion could one draw as to the comparative properties of two actual airplane wings in flight at 120 miles per

hour? The answer is, "Possibly none." The exact condition under which results from tests on models may be applied to actual construction is known. This can best be described by discussing what is called in aerodynamics the "Reynolds number." When a body is moving through the air there are two types of forces acting on it—the air exerts a pressure upon it and there is friction between the moving air and the layer of air sticking tight to the solid. It is not difficult to see that the four physical quantities involved in the aerodynamical action are: The velocity of the air, its density, its viscosity (i. e., measure of the frictional property), and the size of the solid body as given by its length or its thickness. Lord Rayleigh showed many years ago that if we formed the quantity—

$$\frac{\text{density} \times \text{velocity} \times \text{length}}{\text{viscosity}}$$

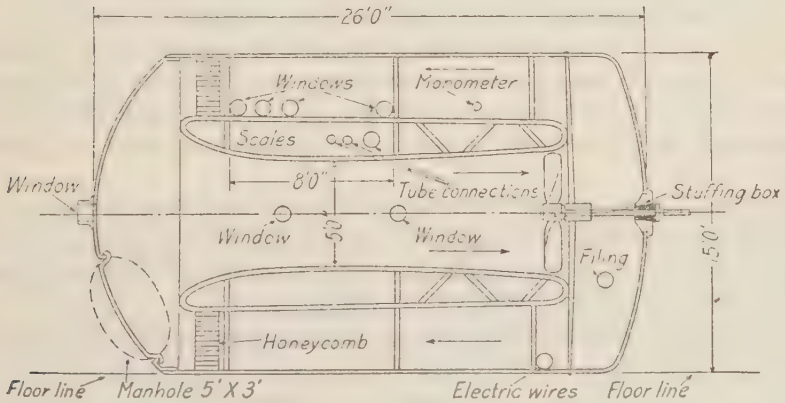


FIG. 7.—Compressed air wind-tunnel.

which is now called the "Reynolds number," we would be justified in saying that the properties observed in any experiment would also be found to be the same for any other experiment having the same Reynolds number. It is seen by looking at the definition of this number that we can have the same Reynolds number for a large number of different experiments. Thus, compare an actual airplane in flight at 90 miles per hour, say, with a wind-tunnel experiment on a model of one-twentieth scale but having the same velocity of air flow. If the Reynolds number is to be the same for the two cases, it is necessary to increase the density of the air in the wind tunnel twentyfold. This shows that if one were to make a wind tunnel in which the air is compressed to 20 or more atmospheres, experiments on models placed in it would give results immediately applicable to full-size airplanes. It is perfectly possible, of course, that

certain properties studied and observed in ordinary wind tunnels at atmospheric pressure may hold also for actual airplanes, but one can not be certain of this until the question is investigated in a compressed-air tunnel. In view of the great importance of this matter, the National Advisory Committee for Aeronautics has designed, and has now under construction such a tunnel, in which the air may be compressed to 25 atmospheres. When completed it will be the only one in the world; and it is expected confidently that a great amount of useful information will be obtained.

I have outlined the experimental methods available for aeronautical investigations, and wish now to state briefly some of the more important ones which occupy our thoughts:

1. Everyone, the world over, is interested in designing a helicopter; but before this can be done we must have knowledge of the properties of a propeller whose shaft is very oblique to the flight path, and we probably shall have to design a new type of propeller.

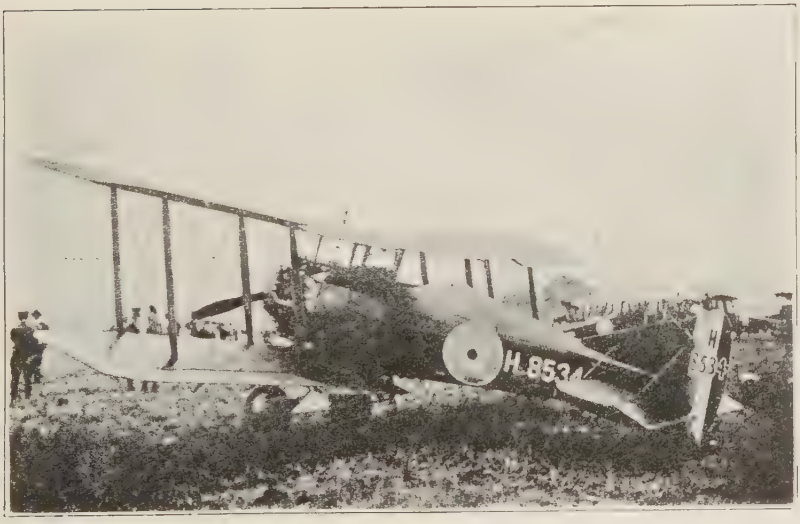
2. A greater range of speed for any one airplane is desirable, so that it may attain a great flying speed and yet have a slow landing speed. In order to secure this possibility, modifications of the wing are essential; and the most promising form at the present time is the Handley-Page slotted wing. Much more research is, however, necessary.

3. Great improvements may be expected in reducing the drag, or resistance, of aircraft, and many researches are now in progress as to the effect of putting the engine and the propeller in different positions, of changing the position of the fuselage, etc.

4. Over 100 different wing forms have been investigated, but our practical knowledge is far from satisfactory, largely owing to the fact that the tests have been made in different laboratories and at different air velocities. Further, of course, the Reynolds number in all tests has been too small. When the compressed-air wind tunnel at the Langley Memorial Laboratory is finished, we will be able definitely to say what wing is best for any specific purpose.

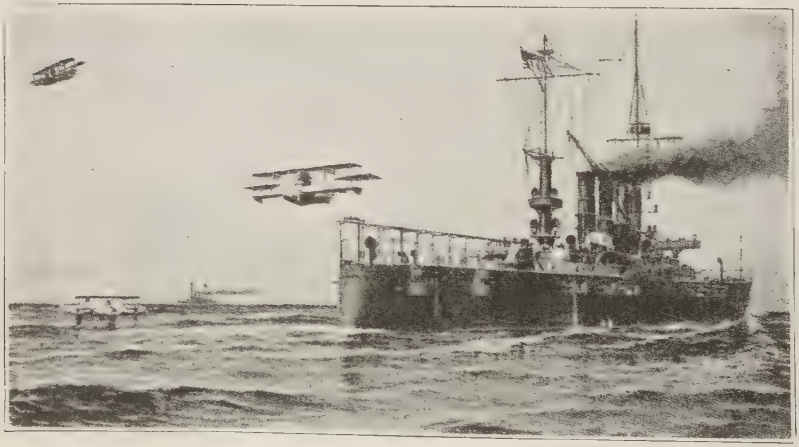
These are simply illustrations of the type of investigations now engaging the attention of aeronautical laboratories, but they serve, I hope, to make clear how interesting the subject is to the scientist and how important to the designer of aircraft.

AIRSHIP, FILLED WITH HYDROGEN. ENGINES AND PROPELLERS; ELEVATORS AND RUDDER; STABILIZING SURFACES.



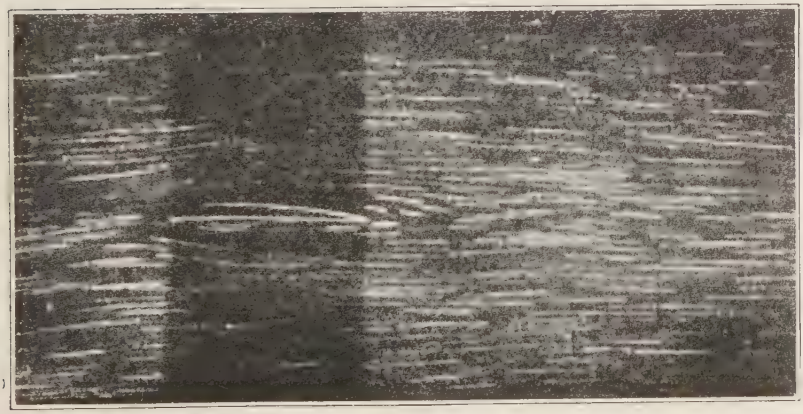
AIRPLANE. WINGS, FUSELAGE, AILERONS, ELEVATOR, RUDDER, ETC.

FOKKER F. III. COMMERCIAL MONOPLANE.

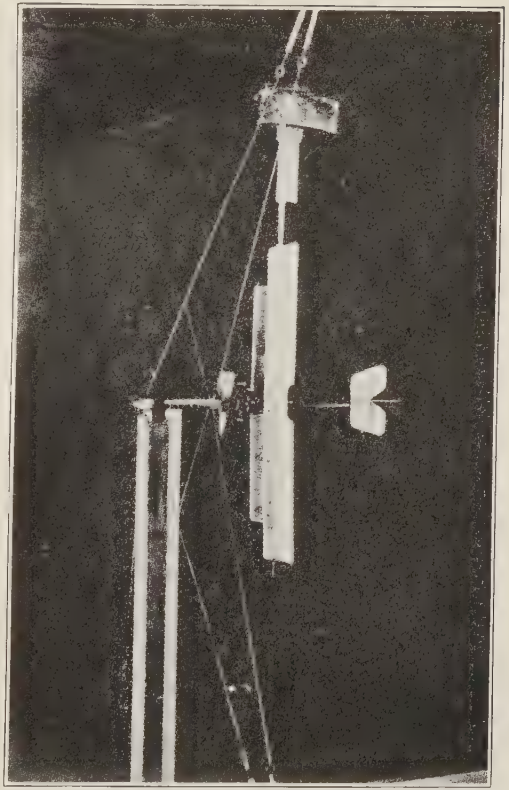


AIRPLANE CARRIER. SEAPLANES IN FLIGHT.

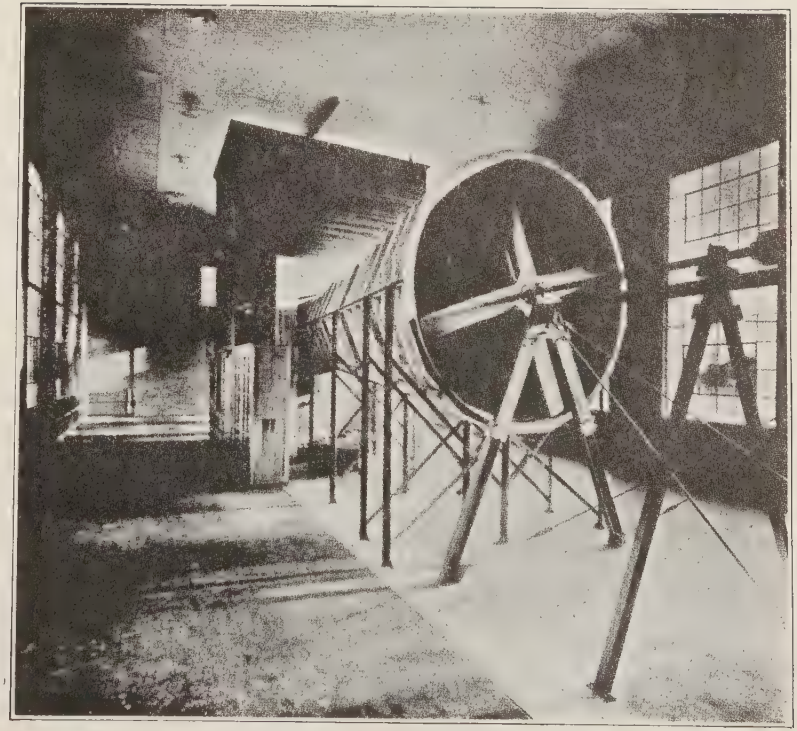
EDDYING FLOW PAST AN AEROFOIL.



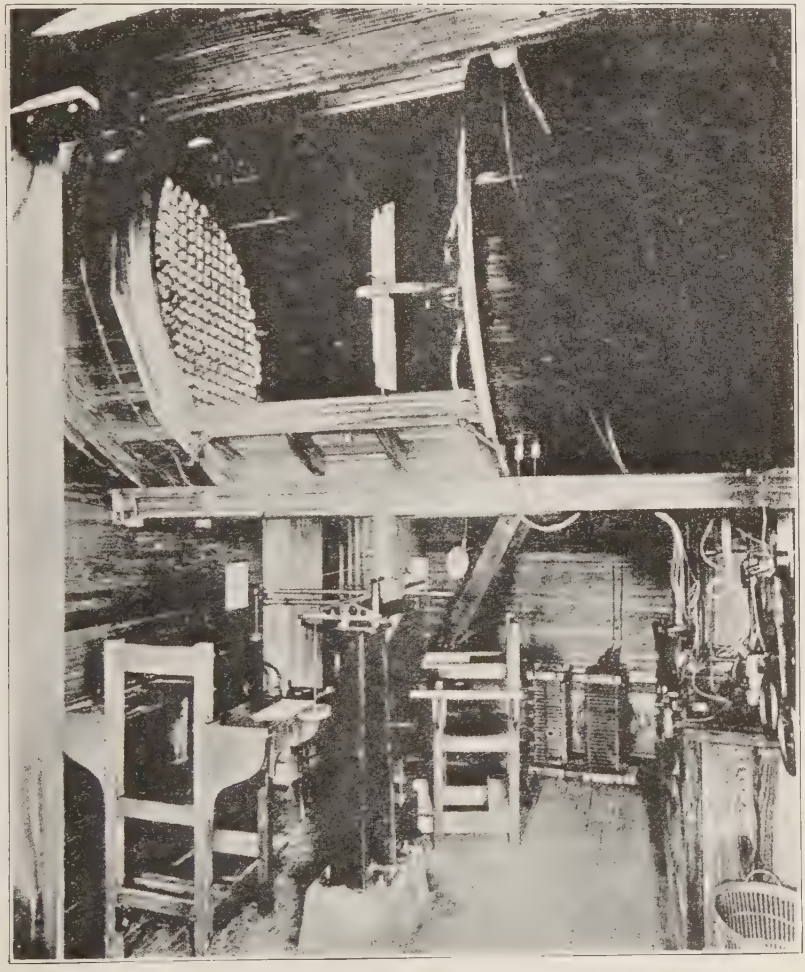
STREAM-LINE FLOW PAST AN AEROFOIL.



MODEL OF A BIPLANE.



EXTERIOR OF TUNNEL, FROM EXIT END.



INTERIOR OF EXPERIMENTAL ROOM AND VIEW OF MODEL SUSPENDED IN TUNNEL.

PHOTOSYNTHESIS AND THE POSSIBLE USE OF SOLAR ENERGY.[1]

By H. A. Spoehr,

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The purpose of the following brief outline is to show that while the photosynthetic process of the plant is at present the only means we have of utilizing solar energy, this method is so very inefficient and subject to such great uncertainties that it is exceedingly doubtful whether it can be depended upon to maintain our energy requirements. In other words, our civilization is using energy at a prodigious rate, and we would be depending upon the exceedingly inefficient and slow process of photosynthesis to supplant the supplies which have been stored for centuries and are now being depleted. Add to this, that in order to supply food for our increasing population no encroachment on agricultural industry would be permissible. Theoretical speculations of the nature of what might be accomplished if, for instance, all the arable land were cultivated, are of no consequence to the problem. Conditions, economic and social, must be faced as they exist. The inertia of our civilization is such that great changes are induced only by the labored movements of evolution or by catastrophe. What part, then, can science and engineering play in the solution of this problem?

First of all, it is the function of scientists to exercise foresight in matters regarding the material welfare of humanity. The experiences of the various scientific bodies called together to cope with the many problems incident to the war, concur in the conclusion that very rarely is necessity the parent of invention where difficult and highly complex problems are concerned. So for this work there will be required an enormous amount of patient labor, which naturally should be begun long before the situation becomes acute.

It has frequently been said of our earth that there are no exports and no imports aside from occasional meteorites. This is true as far as matter is concerned, but it is not true when energy is considered. Matter and energy are the two fundamental entities in our conceptions of all physical phenomena. As scientific thought progresses, ever-increasing attention is being given to the paramount importance of energy relations in the interpretation of natural phenomena. Matter is of interest to us largely in so far as it exhibits certain properties and undergoes definite changes. In viewing the common materials upon which we depend for the maintenance and propagation of life, it is evident that we are less interested in the matter as such than its ability to undergo certain changes which contribute

[1] Reprinted by permission from the Journal of Industrial and Engineering Chemistry, vol. 14, no. 12, December, 1922.

in one way or another to our life activities. From this practical viewpoint, knowledge of the composition of coal, iron ore, sugar, etc., has its ultimate interest in guiding us in the application of such materials to the manifold needs of our complicated physical and physiological economy.

The eminent physicist, Boltzmann, pointed out in his classical exposition of the second law of thermodynamics that the struggle for existence is essentially not a fight for the raw materials that are abundant in earth, sky, and sea, nor for the energies as such, but for the potential energies as in coal, sugar, and meat. Thus energetics commands the center of attention in the consideration of the chemical phenomena exhibited by the various forms of matter, and matter is but a medium for the manifestation of energy.

If our earth were an isolated system in which there were no imports and no exports, our state of affairs would be very different from that which now presents itself to us. According to our experience, formulated in the laws of thermodynamics, in all naturally occurring transformations there is a tendency to arrive at a condition of stable equilibrium. Thus, the substances on the earth are constantly tending to arrive at a condition of greatest entropy, meaning "rundownness." Most of the metals, for instance, are oxidized to their most stable oxides and converted into other compounds which under existing conditions are extremely stable. Our ores are those stable oxides or salts. Although this condition has not been uniformly attained in the earth, while there are still, for example, natural deposits of metallic copper and silver, yet, unquestionably that is the direction in which the chemical changes are proceeding.

Now most of these substances, before they can be made use of, require certain chemical changes which are a reversal of the naturally occurring ones. The ores, oxides or salts of the metals, must be reduced to the elemental metals. This, of course, is the reversal of the processes occurring in nature, and to accomplish such a reversal work must be done, energy must be supplied.

If, then, the tendency is to attain the dead level—this state of equilibrium on our earth—what are the agencies or sources of energy that counteract this tendency and make possible the reverse reaction, the pumping of water uphill, as it were?

In searching for such possible sources of energy which might serve this purpose, we find that a little heat is probably given to the surface of the earth from the interior, another very small amount is the result of certain radioactive chemical changes, the action of the tides contributes some, and a further amount is received from radiation from the stars and moon. But these amounts are quite

inadequate and insignificant when compared with the primal source of our energy, the sun. The radiations from the sun constitute our main source of energy. This is our main and most consequential import, the only potent factor which counteracts the tendency of complete running down. It is important not only in such reactions as the smelting of ores, but equally to the life on the planet.

All living things on the earth demand for their maintenance and propagation a continuous supply of energy. The immediate source of this energy for living things is derived from food. All animals, including man, are fundamentally dependent upon plants for their food. Just as the herbivorous land animals are the source of food of the carnivora, the diatoms are the fundamental source of food of the sea. The object of agriculture is essentially to provide man with such materials from which he is able to derive the energy necessary for the maintenance of his bodily activities, his growth and propagation.

MEANING OF "PHOTOSYNTHESIS."

So far as the composition of food material is concerned, there exists a closed cycle. Man feeds on animals, and animals on plants; the plants feed on the carbon dioxide given to the air by the animals as a result of the latter's use of food. Thus the plant reconverts the waste products of animal metabolism into food. The latter process is called *photosynthesis*. The plant absorbs through its leaves the carbon dioxide which is universally present in the atmosphere, and which is formed by the burning of coal, fuel oil, etc., and is also exhaled by animals. By means of the light from the sun the carbon dioxide thus absorbed by the leaves is changed into material such as sugar or wood, which can again be used as food for animals or as fuel. The net result, as far as the changes of materials are concerned in this interrelation of plants and animals, is nil. Thus, in brief, a plant yields a certain amount of substance which can be used as food. The food is consumed by man and thus enables him to do some work. Thereby the food material is burned in the body and is exhaled as the gas, carbon dioxide. Or the fuel is burned and the products of combustion escape into the atmosphere.

The fundamentally important point is in relation to the energy changes. The energy expended by the man has been permanently lost to a large extent; similarly, that obtained from fuel. The reconversion of the carbon dioxide into food or fuel material can be accomplished only by the use of a great deal of energy. The cycle is made possible only by the introduction of energy from without. This energy is derived from the sunlight, which the plant, unlike the animal, is able to utilize and convert the waste carbon dioxide again into food or fuel material.

It thus becomes evident that all life on the planet depends upon the energy derived from the sun through the intermediary of the plant—i. e., through the process of photosynthesis. Mankind lives entirely on the energy derived from the sun through the pursuits of agriculture.

WASTE OF SOLAR ENERGY.

But in addition to this, we are squandering the principal of an enormous legacy of solar energy accumulated during the past ages. The plants, which alone are capable of utilizing the enormous floods of solar energy pouring upon the earth, have been at work for many ages prior to man's appearance upon the earth and have, during time which would make the total span of human history appear as but a moment, built the foundations upon which all his present eminence rests. This fossil vegetation, preserved as coal and oil, represents a very small fraction of the energy which has been falling on the earth and which has been conserved for man. It is kindled, its energy liberated and used in a thousand ways, and the rays of sunlight stored beneath the earth for millions of years give birth to a civilization such as the world has never known. It is this source of energy which has made possible the habitation of the temperate zones to the present extent, and on it depend our various modes of rapid transportation and our multifarious industrial activity. What may be called fossil solar energy, coal, made possible the reversal of the natural course by the smelting of ores for the production of metals. In fact, it is solar energy which counteracts the tendency of our earth to attain its maximum entropy.

But this great civilization of coal and steel is at the same time a most squandrous and profligate one; it is using the principal of its legacy in numberless new ways. Modern man's greatness depends upon his being essentially a tool-using animal. To increase the efficiency of one-man power has been his object for centuries. It is the power-driven machine that has done most of his work. But the source of energy which drives these machines is not a steady stream, it is being drawn from the accumulation of centuries. A year's consumption of coal at the present rate represents the accumulation of hundreds of years. The power of man to do work, physical work, the unit one-man power, is now an almost insignificant factor. A return to such a physical standard would almost certainly follow the failure of such sources of energy as man now has at his disposal. The quest of these sources of energy, coal and oil, is at present being pushed with a feverish intensity that has never been known before, and the competition for the possession of these stores recognizes no principles. The destiny of civilization is guided by and reflects the amount of available energy. When coal and oil

are exhausted the daily ration of solar energy will represent almost the entire means of livelihood; our mushroom civilization must pass like the historic empires of the past and we may expect the reappearance in the world once more of galley slaves and serfs.

ENERGY RESOURCES AVAILABLE.

And thus the scientific world is awakening to the necessity of taking stock of our available resources of energy. Repeatedly, attention has been called to the inexhaustible floods of solar energy. With cool theoretical nonchalance the untold possibilities of the use of the sun's energy are constantly called to our attention. Yet the chlorophyllous plant still remains the only converter of solar energy.

The student of photosynthesis can not, even if he would, escape the practical applications of the problem. It is largely due to the fact that photosynthesis has been dealt with in an academic manner that its fundamental significance has until very recently not been more generally recognized and it has not been possible to enlist the interest and cooperation of workers in the allied sciences. To anyone who has been actively engaged in the investigation of this problem it must be evident that progress toward its solution would be enormously accelerated by cooperative efforts from different angles.

Recently interest in the subject has been very greatly stimulated through the realization on the part of industrial scientists that our available supplies of energy are being rapidly depleted.

Our main source of energy is coal, and although it is less than 100 years since it has been put to extensive use as a fuel, the present annual consumption is stupendous—about 650,000,000 tons. Each decade has brought a decided increase in the rate of consumption. While there are, of course, still enormous supplies to draw upon which, considered superficially, might allay all concern, our engineers, most qualified to judge, have repeatedly called attention to the necessity of preparedness on the fuel situation.

A far more serious situation is presented by the petroleum supply. The rapid development of internal-combustion engines of various types has brought about a tremendous demand for liquid fuel. This has increased at such a rate that it can be conservatively stated that the depletion of the petroleum supply in the United States is clearly in sight. A report of the country's foremost oil geologists, under the auspices of the United States Geological Survey, states:

> The estimated reserves are enough to satisfy the present requirements of the United States for only 20 years, if the oil could be taken out of the ground as fast as it is wanted.
>
> Individual wells will yield oil for more than a quarter of a century, and some of the wells will not have been drilled in 1950. In short, the oil can not all be discovered, much less taken from the earth, in 20 years. The United

States is already absolutely dependent on foreign countries to eke out her own production, and if the foreign oil can be procured this dependence is sure to grow greater and greater as our own fields wane, except as artificial petroleum may be produced by the distillation of oil shales and coals or some substitute for petroleum may be discovered.

It is, therefore, not surprising that every available source of energy is being considered to meet the situation which is approaching.

Another very considerable source of energy is that developed from the water powers. Theoretically, this is virtually an inexhaustible supply and one of relatively high efficiency. Mr. Charles P. Steinmetz [2] has calculated, on the basis of collecting every raindrop which falls in the United States and all the power it could produce on its way to the ocean being developed, that there would be possible about 300,000,000 horsepower. This enormous figure represents about the amount received from our present total consumption of coal. Thus, this theoretical hydroelectric power would just about cover our present coal consumption, but leave nothing for future increased needs or to cover other sources of energy now in use. Moreover, this figure for hydroelectric power is purely hypothetical, of which only a small fraction represents that actually available, which, when united with other difficulties such as equipment and limitations of distribution, shows very clearly that all the water powers of the country can not suffice.

The question of liquid fuel is of particular importance in this consideration. The great success of the internal-combustion engines in the automobiles, airplanes, tractors, etc., as well as the many uses of the Diesel engine, has very greatly influenced our economic life and, as has been stated, it is soon to exhaust our natural resources of liquid fuel. Much attention has, therefore, been given to the production of liquid fuel other than petroleum. Thus far the investigations along these lines have almost universally led to the opinion that the substance best suited to these needs is alcohol. This is on the basis that alcohol can be produced from vegetable material and is the most direct route from solar energy. It is thus proposed to develop a photosynthetic industry on the basis of agriculture, the products of which are to be converted into alcohol by means of fermentation.

This is, of course, the practical end of the photosynthesis problem. There are so many factors which come into consideration on careful study of the problem in its broadest application, that it is not surprising that some of the most important of these have been entirely disregarded or not given the attention they deserve.

[2] "The White Revolution," Survey Graphic, 1 (1922), 1035.

POSSIBILITIES OF PHOTOSYNTHESIS.

In considering the sun as a source of energy two possibilities suggest themselves. The first is a direct utilization of solar energy through some device by means of which the energy could be transformed and stored; the other is by means of the natural process of photosynthesis. Disregarding as inadequate those arrangements that transform solar energy into heat and attempt to use boilers of various kinds, no advance has been made in the direct utilization of solar energy. A transformation of the energy based upon chemical methods has received little attention. The reason for this is that such known photochemical reactions as are endothermal—that is, processes in which energy is stored—are not of a nature to encourage development. The process of photosynthesis in the green plant is such a transformation and storing of energy. Nature has worked out this problem and has done it in a most remarkable manner.

We are therefore still centering our speculations on the plant as a transformer of energy through the production of carbohydrate material. With complete disregard of biological facts, chemists have continued to develop schemes for the employment of the photosynthetic process and to evolve theories of the chemistry of photosynthesis. One of the fundamental fallacies in these speculations may be indicated by a quotation from a recent technical article: "Photosynthesis is simply a manufacture that provides material used in the process of living." It is falsely conceived that this process of manufacture is not a function of the living plant.

There have also been many erroneous and misleading statements regarding the amount of energy radiated from the sun which reaches the surface of the earth. In nearly all the technical discussions on this subject that have appeared recently the calculations are based upon the value of 3 calories per square centimeter per minute. Now, this value does not represent the amount of energy which reaches the earth. It is the old value of the solar constant; i. e., the amount of solar energy at the outside of the earth's atmosphere.

The true value of this solar constant is still a subject of some dispute, and it is in fact of secondary interest to the immediate problem of the utilization of solar energy on the earth. A great many determinations of the amount of energy received on the earth have been made, and it is certain that a very considerable amount of solar radiation is absorbed in the atmosphere of the earth. For the present purpose the intensity of solar radiation reaching the earth can be placed at 1.5 calories per square centimeter per minute. On this basis we would receive 5,400 large calories per square meter during six hours. Now, 1 kilogram of coal when burned develops about 8,000

large calories, so that six hours of insolation per square meter represents a heat equivalent of 0.675 kilogram of coal, and on an acre 16.41 tons of coal. This for 90 days of insolation would equal 1,476.63 tons.

In order to gain some idea of the degree of efficiency of the photosynthetic process in utilizing solar radiation as expressed in the yield of agricultural products, the heat value of a cereal crop can serve as a comparison. Taking the very large yield of 50 bushels, or 17.619 hectoliters of wheat per acre, and considering this as entirely starch, we get an energy equivalent of 0.623 ton of coal. This last figure of about two-thirds of a ton of coal is to be compared to the 1,476 tons, representing the total solar radiation during a period of 90 days, approximately a growing season.

This, then, is the amount of solar energy received at the surface of the earth and in a practical sense the amount of this energy that is stored by means of agriculture. It is a very striking fact that the processes of organic nature are exceedingly inefficient and wasteful. This, of course, is so of necessity. Faced with the uncertainties of environmental and climatic conditions, only such processes as are allowed a wide margin of safety are assured the living organism of survival. These figures also indicate that agriculture, as the only photochemical industry, is utilizing but a very small portion of the available energy.

In discussing the possibility of preparing liquid fuel from grain, Boyd[3] makes the following statements:

> The large amount of motor fuel required seems to exclude the possibility of preparing any considerable percentage of the necessary amount from foodstuffs. In illustration of this statement the following figures are of interest:
>
> | | Bushels. |
> |---|---|
> | Average annual United States production of corn, 1913–1919 | 2,740,000,000 |
> | Average annual acreage in corn, 1913–1919 | 160,000,000 |
> | Alcohol from the corn at 2.75 gallons per bushel | 7,500,000,000 |
>
> The heating value of this amount of alcohol is about equal to that of 5,000,000,000 gallons of gasoline. The production of gasoline in the United States during 1920 was very close to this amount, about 4,900,000,000 gallons. The average acreage in corn as given above is equal to 166,000 square miles, which is more than four times the total area of Ohio. In view of the fact that the possible alcohol production from corn represents close to 60 per cent of the total possible amount of alcohol that could be prepared from all of the starch and sugar containing foodstuffs produced in the United States, and that such a large acreage is required for its production, the possibility of a sufficiently large increase in production of such materials to be diverted to the manufacture of motor fuel seems very unlikely. At any rate, if large quantities of motor fuel are to be prepared from vegetation, another material, if not instead of foodstuffs at least in addition to foodstuffs, must be relied upon as a source.

[3] "Motor Fuel from Vegetation," Journal of Industrial and Engineering Chemistry, 13 (1922), 836.

It seems highly questionable whether the use of the products of photosynthesis offers a rational solution to the problem of industrial energy. It must be borne in mind that the products of photosynthesis are essential to human life as the fundamental source of food. The trend of modern investigation of the chemical, as well as the economic phases of the food problem, strongly supports the dictum that agriculture will always be the basis of food production and that this can not be supplanted by any artificial method. The materials which are elaborated by plants are directly essential to the well-being of man. Furthermore, any serious disturbance in the way of diverting agricultural products from their use as food to industrial ends would undoubtedly be fraught with profound economic disturbances.

CELLULOSE AS SOURCE OF FUEL.

There is one other plant product about which there has been much speculation regarding the possibilities as a source of liquid fuel; that is cellulose. There are so many factors which enter into a rational consideration of the possibilities of producing alcohol from cellulose that no adequate analysis of the problem has as yet been attained. These factors embody the biological aspects, the chemical methods, and the economic possibilities. It can not be claimed that any one of the many compilations and discourses offered since the great interest in this subject has arisen treat adequately the complexities of the problem. Briefly, the points that demand consideration are the availability of cellulose material in sufficient quantity and the continuous supply thereof, an exact and broad knowledge relative to the chemical processes of converting cellulose to alcohol, and the cost of raw material, manufacture, and transportation, as well as the complexities of labor and influence on other industries. In different sections of the country where different kinds of wood come into consideration there are problems peculiar to each locality.

Much of the speculation as to the use of cellulose for conversion into alcohol is based upon the utilization of waste material in the forests and at the mills. Of the 26,000,000,000 cubic feet of wood cut annually, the major portion represents accumulated virgin timber, so that this source can not be considered as a permanent one. To what extent and how soon the depletion of virgin forests will be met by intensive forestry is a practical question that seems difficult to answer.

These considerations also obtain for the frequently repeated statements of the use of humid tropical regions for growing material from which alcohol could be manufactured. It must be borne in mind that for any such undertaking reliance could not be placed upon extant material, recourse would have to be taken to very ex-

tensive cultivation. Moreover, such an undertaking must not interfere with the area now used for the production of foodstuffs.

COMPLEX NATURE OF AGRICULTURAL INDUSTRY.

Finally, in advocating the natural photosynthetic process through agricultural industry as the producer of a supply of energy there has been evidenced great neglect of the fact that agriculture is a highly sensitive and complex industry. The fact seems to be too readily forgotten that agriculture deals with biological processes, that solar radiation is but one of many factors influencing the developments of plants, and that in almost every place on the earth where agriculture might be undertaken there is far more light than the plant is capable of utilizing.

The uncertainties of agricultural industry arise from the very complex nature of the biological processes and balances involved in the development of a growing organism. Not only the multiplicity of pests and diseases with which agricultural endeavor must contend, but the relatively sensitive adjustment to climatic environment increases the hazards of this industry enormously. Thus, of course, the growth of plants is not dependent on light only, but on a variety of factors not associated with solar radiation.

The fact that during critical periods in the development of a plant slight changes in climatic conditions during a short time may greatly reduce or entirely destroy a crop, serves to emphasize the hazard of obtaining energy through the intermediary of plants. In agriculture, water supply and temperature are far more variable and determining factors than light intensity. On the proper coordination of these two factors, probably more than any other, depends the success of crop production.

On the other hand, considering alone the solar energy which it is our object to store, there falls on the earth during most of the year a great deal more than any plant is capable of utilizing.

SOLUTION OF THE PROBLEM.

Nature has worked out a method of utilizing solar energy. It is the duty of the scientist to learn the precise manner in which this is accomplished. He need not be timid about competing with nature. He has many cases to his credit of surpassing the processes of nature both in efficiency and reliability. There are many substances now effectively produced artificially which were formerly obtainable only from plants or animals. It is true that in the utilization of radiant energy there are a great many intricate difficulties to be overcome, but to anyone who has given the problem thorough study it

must be evident that we are already in possession of much knowledge which can find immediate application to this problem. As the basis of agriculture, the problem of photosynthesis needs development and clarification. As the only known photochemical reaction, proceeding in the visible spectrum, in which there is a large increase in the potential energy of the products, photosynthesis serves as a guide to the utilization of solar energy. Although the chemical reactions constituting the photosynthetic process are of a highly complex and intricate nature, sufficient investigation has been done to justify the conclusion that the problem is amenable to physico-chemical treatment. However, no single academic division of science, such as botany, chemistry, or physics, is of itself sufficiently rich in concepts and methods to attack the problem adequately. The most promising outlook for success in this field would be offered through an organization by which information from the various allied fields can be collected and focused on the chemical and energy changes taking place in the process of photosynthesis. In view of the present academic division of the sciences and the variety of special training which is requisite for such an undertaking, cooperative effort offers the only rational method of advance.

Photosynthesis is essentially a problem of energy transfer. Those aspects of the problem involving the changes of material, the rates of these changes, and the conditions under which they occur, require the methods and conceptions of organic chemistry and physiology. In order to determine the kinetics of these same reactions and the mode of energy transfer, a very different method of experimentation is required. These latter lead directly to the fundamental problems of radiochemistry and require the most advanced methods of physical experimentation.

Has not science here a unique opportunity to lead the way in real cooperation and to demonstrate its true democratic value?

The embryo of a seed, during its first days after sprouting, lives upon material stored for it by the parent, until it gains strength and becomes an independent plant. Throughout nature the young are nurtured and protected until they can care for themselves. So man has had his great patrimony of fuel to help him in his first faltering steps to dominion over his environment. As he grows in intellectual stature, he must meet the problem of physical necessity, a problem of energy pure and simple, ere he can aspire to true independence. The great contribution of the nineteenth century was the establishment of the doctrines of energy. To the twentieth falls the task of freeing us from our economic placenta.

FOGS AND CLOUDS.[1]

By W. J. Humphreys, C. E., Ph. D.,

Professor of Meteorological Physics, United States Weather Bureau, Department of Agriculture.

[With 26 plates.]

EVAPORATION AND PRECIPITATION.

WHERE FROM AND WHERE TO.

Everyone knows that rain and snow come out of the clouds, and that every cloud and fog particle is either a water droplet or an ice crystal. Naturally, therefore, one asks where all this endless supply of water comes from; endless, because year after year, century after century, and age after age, rain and snow have descended as they now descend. And where, too, does it all go, this world average of 16,000,000 tons a second? The answers are: It comes from the soil and its vegetation, from rivers, lakes, and the oceans; and to them it returns—an endless cycle of evaporation and condensation.

> "The mist and cloud will turn to rain,
> The rain to mist and cloud again."
> —*Longfellow.*

EVAPORATION.

The first of these processes, namely, evaporation, consists in the change of water (water in this case, though many substances behave similarly) from the liquid, or even solid, state to that of an invisible gas, in which condition it becomes an important, though always relatively small, part of the air we breathe.

The rate of this evaporation depends on a number of things, the more important of which are:

(*a*) The area of the evaporating surface. The larger the surface the more rapid the total evaporation. It is in recognition of this law that we spread out a drop or even a puddle of water to hasten its disappearance.

[1] Based on a lecture given before the section of physics and chemistry of the Franklin Institute on Jan. 5, 1922. Reprinted by permission from the Journal of the Franklin Institute, February–March, 1922.

(*b*) The temperature of the evaporating water. The higher this temperature the more rapid the evaporation. That is why heating things hastens their drying.

(*c*) The velocity of the wind to which the water is exposed. This explains why roads, for instance, dry so much quicker when the winds are strong than when they are light.

(*d*) The amount of moisture already in the atmosphere. The wash on the clothesline, as every housewife knows, dries provokingly slowly during cloudy, muggy weather.

All the other factors that affect the rate of evaporation, such as density of the air, saltiness of the water, etc., generally are small in comparison with the above, and need not here be considered since it is only intended to make perfectly clear, through our everyday experiences, the wide occurrence and great importance of evaporation.

SATURATION.

Although evaporation, as just stated, is so very general there are conditions under which things will not dry, nor bodies of water any longer decrease. Thus even a rather small amount of water in a tightly closed bottle, or other impervious vessel, remains there indefinitely. The space above the water becomes saturated, we say, by which we mean that it gets so charged with water vapor that, under the existing conditions, it can contain no more. At this stage the net evaporation is zero. That is, the amount of the invisible water vapor that now goes back, or condenses, into the liquid stage is exactly equal to that which, in the same time, leaves the liquid surface and becomes invisible vapor. In other words, at this stage, however rapid the interchange between liquid and vapor, the amount of each remains constant.

Numerous careful experiments have determined very closely the exact weight of water vapor per cubic foot, say, when the space in question is saturated at any given temperature, from the boiling point to far below that of freezing. And these experiments show two facts of paramount importance in the formation and dissipation of clouds, namely:

1. The amount of moisture necessary to produce saturation increases rapidly with increase of temperature.

2. The amount of water vapor essential to saturation is not appreciably affected by the presence or absence of the other gases of the normal atmosphere.

It is true that even in technical language we often say that the *air* contains such or such an amount of moisture, as though the presence of the air was essential to the existence of the vapor, or as though the air acted somehow like a sponge in taking up water. But,

as explained, this idea is wholly wrong. The only appreciable effect of the presence of the other gases of the atmosphere on the moisture is that of slowing the rate of its spread or diffusion. Temperature and temperature alone, to within a negligible amount, determines the quantity of vapor per any given volume necessary to produce saturation, or, of course, any definite percentage or fraction of saturation.

CONDENSATION.

The percentage of saturation produced by a given amount of water vapor may, therefore, as is obvious from the above discussion, be varied by altering the volume it occupies or its temperature, or both; and as rapidly as saturation tends to be exceeded moisture condenses out onto any water surface or solid that may be present. Thus, the deposition of dew, the formation of hoarfrost, and the sweating of ice pitchers all are examples of condensation owing to passing the saturation point or dew point, as it commonly is called. In these cases just mentioned the temperature of the water vapor and, of course, of the other constituents of the atmosphere, which, however, play no part in the condensation, is lowered through contact with cold objects, and the volume of this vapor, as well as that of the accompanying chilled gases, decreased—decreased because in the open air the pressure remains constant, or nearly so, whatever the degree of cooling.

Similarly, whenever the temperature of the open air passes below the dew point condensation occurs in the form of innumerable water droplets or tiny ice crystals throughout the chilled volume, and thereby produces a fog or a cloud, as determined by location—a fog if on the surface, a cloud if only in mid-air.

The natural processes by which a given body of the atmosphere may be sufficiently cooled to lose a portion of its water vapor by condensation are: (1) Contact with objects colder than itself; (2) mixing with colder air; (3) radiation; (4) expansion.

Condensation as a result of contact cooling is well illustrated, as already explained, by the deposition of dew—the bedewed objects having been cooled by radiation; by the formation of hoarfrost, which occurs under the same conditions, except at a lower temperature, as does dew; and by the sweating, during warm humid weather, of all cold objects. It is further illustrated by the formation of fog, generally light, when relatively warm humid air drifts over a snow bank or other cold surface.

The second of the above processes of inducing condensation—that is, the mixing of masses of humid air of different temperatures—is not very effective. Indeed, an accurate calculation, based on the

temperature and volume changes and other factors of the problem, shows that while a fog or cloud may be obtained by this process no appreciable amount of rain or snow is likely to result. Layer or stratus clouds at the boundary between relatively warm air above and cold beneath, a phenomenon of occasional occurrence, are at least partially due to mixing, as are also the fogs that so frequently occur over adjacent warm and cold ocean currents.

The third process by which air loses heat, namely, by radiation, probably is of little importance in the production of clouds, since the most chilled portions of free air sink to lower levels and thereby become even warmer and drier than they were at first. Near the surface, however, where descent and the consequent dynamical warming, as it is called, are impossible, radiation often is very effective in the production of fog.

The last of the cooling processes mentioned above—that is, expansion—is exceedingly effective, and to it is due the great bulk of cloud formation. Now, expansion of the air may be produced either by heating it or by reducing the pressure to which it is subjected. It is the latter process, obviously, and not the former, even though heating generally is the initial cause, that produces the cooling of free air and the formation of cloud. To make these points clear, consider the results when a given mass of humid air is heated, as it may be, over a region warmed by sunshine or otherwise. With increase of temperature it expands and thereby becomes lighter, volume for volume, than the surrounding cooler air. The surrounding denser air then underruns the lighter and lifts it up to higher levels, just as hot air is driven up a chimney. As the warmed air is thus forced up (rises, as we generally say) the pressure to which it is subjected obviously decreases in proportion to the weight of the air left below. It therefore gradually expands as it rises and thereby does work, and since the only energy available for this work is the heat of the ascending air, it follows that as its height increases its temperature must correspondingly decrease. As a matter of fact, for air of average humidity, the rate of this decrease is approximately 1° F. per 187 feet increase of elevation up to the base of the cloud, if there be one, in the rising air, and then much less through the cloud. In any event the ascending air attains equilibrium only when it has cooled by expansion to the temperature of the air that finally surrounds it. Hence, when it comes to rest, it is colder, often much colder, than it was before it was heated.

Of course the expansion of the rising air correspondingly increases the vapor capacity, but it is easy to show, both theoretically and experimentally, that this increase of vapor capacity by volume expansion is small in comparison with its simultaneous decrease through

the lowering of the temperature, and that convectional expansion, therefore, whether incident to the blowing of wind up and over mountains, or to local heating, is a most effective means of inducing condensation and the formation of clouds.

CONDENSATION NUCLEI.

Whenever ordinary air, kept humid by the presence of water, is suddenly expanded in a closed vessel, it instantly becomes filled throughout with a miniature cloud, precisely as occurs on an incomparably larger scale in nature. Subsequent expansions of the same air, otherwise undisturbed, induce less and less cloud, and presently none at all. If filtered air—that is, air drawn through several inches of cotton wool, or other substance of similar texture—is used, condensation by moderate expansion is impossible from the first. The admission, however, of a little smoke restores to the exhausted air, and endows the filtered air with, full powers of condensation. There are, therefore, condensation nuclei in the atmosphere—hundreds and often thousands of them per cubic inch—which can be filtered out; and microscopic examination shows that they consist essentially of dust particles. Hence, dust, moisture, and some cooling process are the three essential factors in all natural fog and cloud formation.

It is true that a few substances other than dust, such as the oxides of nitrogen, act as condensation nuclei, but they seem generally to be negligible in quantity. Furthermore, condensation can be obtained in air wholly free from any such nuclei provided it is ionized and forced to at least a fourfold supersaturation, a degree of humidity that probably never occurs in nature. Indeed, under very great supersaturation, eight or nine fold, condensation occurs even in perfectly clean nonionized air. But this, too, is only a laboratory experiment, and not a process by which clouds are formed in nature.

FOGS.

DISTINCTION BETWEEN FOG AND CLOUD.

As already explained, whenever the air is cooled, by any means whatever, below its dew point, a portion of the water vapor present separates out on such dust particles or other condensation nuclei as happen to be present. If this process occurs only at a considerable distance above the surface of the earth, leaving the lower air clear, the result is some form of cloud. If, on the other hand, it extends quite to, or occurs at, the surface of the earth it is then called a fog, no matter how shallow nor how deep it may be. The distinction, therefore, between fog and cloud is that of position. Fog is a cloud on the earth; cloud, a fog in the sky.

In some cases the only basis of distinction between fog and cloud is that of viewpoint. For example, the mist that sometimes covers only the crest of a mountain generally is called fog by those actually in it, and cloud, at the same time, by those in the valley below.

WHERE AND HOW FORMED.

Fogs are likely to form along rivers and large creeks and in the mountain valleys of all but arid regions in the latter part of any still cloudless night of summer or autumn. During these seasons the streams and the humid soil are warm, especially when exposed to sunshine, and hence evaporate much moisture into the lower atmosphere, where, in great measure, it remains when there are no winds to blow it away.

Throughout the night, however, the surface of the soil and the adjacent humid air, by virtue of its humidity, lose heat rapidly by radiation to the colder atmosphere above and to the sky, or empty space, beyond. This loss of heat by radiation is no greater, of course, by night than in the daytime, but when there is no sunshine to make good such loss, or do better—as generally is the case through the forenoon—the inevitable consequence is a lowering of the temperature. Hence, during calm, clear nights the temperature of the humid surface air often falls below the dew point and a fog of corresponding depth and density is formed.

If the sky is overcast there commonly is enough radiation from the clouds back to the earth, especially if they happen to be low (hence warm), to prevent the cooling of the surface air to the dew point and the consequent formation of fog. Neither does fog form when there is considerable wind, partly because the more humid lower air is then mixed with the drier upper air and the surface dew point thereby lowered, and partly because this mixing prevents much fall in the surface temperature by distributing the loss of heat through a relatively large amount of air instead of leaving it confined essentially to that near the ground. Hence fogs of the kind under consideration—radiation fogs, summer fogs, land fogs, valley fogs—seldom occur either when the sky is cloudy or the night windy.

Another source of numerous fogs is the drifting of relatively warm humid air over places much colder, such as the drifting of on-shore winds over snow banks. In this way the humid air frequently is cooled below its dew point and fog—"winter fog" or "sea fog"—produced. Likewise, heavy fogs often are formed when the wind is from warm to cold water—from the Gulf Stream to the Labrador Current, for instance.

Fogs also frequently occur when cold air slowly flows in over warm water. This explains the "frost smokes" of polar seas, and the "steaming" of rivers and lakes on cold frosty mornings. In these cases the relatively warm water goes on evaporating into the cold air even after it becomes saturated and thereby produces a water droplet or a minute ice crystal about every one of the myriad millions of nuclei present. If, however, the cold air comes in with a rush—that is, if it enters as a strong wind—no fog is produced, simply because the vapor is distributed by the accompanying turbulence through too large a volume to produce saturation.

KINDS.

In respect to the ways in which they are formed, fogs may be divided into two classes:

1. *Radiation fog* (pl. 1, fig. 1), due to the cooling of the lower air below the dew point, partly by its own radiation and partly by contact with the surface which itself had cooled by radiation. This type of fog is common, as already explained, along streams and in valleys where, through the summer and autumn, it is apt to occur on any calm, clear night.

2. *Advection fog* (pl. 1, fig. 2, and pl. 2, fig. 1), produced by the advection or horizontal movement of air from one place to another such as the drifting of relatively mild air from the ocean inland over snow banks, or from a warm current to a cold one; and the flow of frosty air over open water. Furthermore, any fog when shifted to a new position may then be called advection fog. Usually, too, the shifted fog, like that so common on many leeward coasts, is advective also in origin.

There also are several other classifications of fogs, less scientific perhaps, but often very convenient. Thus we speak of *dry fog*, meaning a fog which, because of the small amount of water content, does not wet our clothing—evaporates as fast as caught up—or else meaning, as we often do, a haze caused by a forest fire, dust storm, or volcanic explosion; *wet fog*, meaning one containing so much water that, like a Scotch mist, it makes at least the surface of one's clothing distinctly damp; *sea fog*, fog originating on the ocean, whether remaining there or drifting on shore; *land fog*, one occurring in the country and which, as its nuclei are but slightly hygroscopic, quickly evaporates; *city fog*, one occurring over a city, especially a city that uses a large amount of soft coal and has but few smoke consumers, generally slow to evaporate, owing jointly, presumably, to the hygroscopic nature of the nuclei and to the oil in the unburned sooty smoke; *black fog*, one containing a great amount of soot, such as occasionally forms over large, smoky cities; *pea-soup fog*, a local name

given to those London fogs that contain only a moderate amount of smoke particles—just enough to give the fog a distinctly yellowish cast; *ice fog*, or "frost smoke," the fog of polar seas, caused by the drifting over them of very cold air; and many others, mostly of less interest and of small importance.

QUANTITY OF WATER CONTAINED.

It might seem, on first thought, that it would be a very easy thing to measure the amount of liquid water in a given volume of fog, but this amount is so small that even tolerably accurate measurements of it require much care. Nevertheless, it has been reliably measured. Thus, in the course of an official ice patrol cruise on the *Seneca* about the southern edge of the Grand Banks of Newfoundland, that is, in the region of one of the most frequented of the steamer lanes, Wells and Thuras measured the water content of a dense fog that occurred on the evening of May 9, 1915. In this fog there were about 20,000 droplets per cubic inch. In their report they say: "To gain some idea of the order of magnitude of the quantities involved in this dense fog, assume that one can not see beyond 100 feet. A block of fog 3 feet wide, 6 feet high and 100 feet long contains less than one-seventh of a glass of liquid water. This water is distributed among 60 billion drops."

Barely one good swallow!

SIZE AND NUMBER OF PARTICLES.

The size of fog particles is easily and accurately determined by looking through the fog at a point (pinhole) source of bright light and noting the difference in direction toward center and circumference of any definite one of the rings of colored light seen around this source—rings of precisely the same nature as the coronæ produced by thin clouds around the sun and moon. This angular size, or difference in direction between center and circumference of any one of these rings, increases as the diameter of the fog particles decreases, and in such known and definite manner that when either is given the other can at once be accurately calculated.

If then, we know the size of the fog particle and if, in addition, we know the amount of liquid water in a given volume of fog, which, as explained above, can be measured, it obviously is only a matter of easy arithmetic to find the number of such particles per cubic inch, say, or any other given volume.

These sizes and numbers, however, are surprising. Everyone knows, of course, that a fog droplet is small, but not many, perhaps, realize that 2,500 of them, of the average size, placed side by side in a single row would extend only one inch, or, in other

words, that it would take half an hour to count a string of them an inch long! Nor is the number of fog particles in a definite volume any less amazing. It is but a light fog that has only 1,000 droplets per cubic inch; a heavy fog has around 20,000. Indeed, vastly greater numbers have often been found, even up to nearly a million per cubic inch.

But these droplets, as explained, are so excessively minute that the very maximum density of a million per cubic inch would still leave the empty space 30,000 times greater than the volume actually occupied by all the liquid present.

IMPRESSIONS.

If one would thrill his soul with beauty let him, on a brilliant, moonlit night, view from the mountain's crest a far flung fog over all the Piedmont region beyond, with foothills and knolls rising here and there as so many enchanted islands in an enchanted sea. Let him, as the dawn breaks clear, gaze from a mountain top on an incipient, fibrous fog, covering a neighboring valley with a fabric more gauzy and delicate than ever Arachne spun. Let him stand on the topmost peak of rugged Tamalpais and watch in wonder the mighty fog billows crowd through the Golden Gate, break over the barrier mountain crests, and rush down their sides in an all engulfing flood. Let him view from afar the snow-crowned crest of incomparable Fuji, floating without visible support, in a clean, clear sky while all its base and the region around is lost in deep fog and delicate mist.

These are but some, and typical, of the most beautiful and fascinating of fog effects; so impressive, indeed, that we could not forget them if we would, and so charming that certainly we would not forget them if we could.

But the impressions produced by fog are not always so charming and entrancing. If one would go quite to the opposite extreme and experience its terrors, let him get lost in London's darkest and densest fog. Let him be alone at night in an unfamiliar forest and have settle down upon him so thick a fog that literally he can not see his hand before him. Let him, on the ocean in the dead of night, between the shrieks of his own ship's siren hear from somewhere, just somewhere, within the encircling gloom, the same dread warning. Let him, when flying over strange territory, be forced to land in a deep, dense fog!

All these, and many others, are horrors one longs to forget, but can not.

And so it is that, from extreme to extreme, from fascination to fear, from delights we fondly cherish to dreads we would fain

forget, fog in all its moods and circumstances plays compellingly upon the whole gamut of human emotions.

CLOUD FORMS.

It is passing strange that the ancient Arabs, Greeks, and others should have given a name to every portion of the heavens, and to numerous individual stars—names still in current use throughout the civilized world—and yet have failed to name any one of the many kinds of clouds that are even more conspicuous in the sky than the stars themselves or their constellations. Perhaps giving them names long seemed both useless and impracticable owing to their infinite variety and ceaseless changes, for indeed, as Shakespeare puts it:

> Sometimes we see a cloud that's dragonish,
> A vapour sometimes like a bear or lion,
> A towered citadel, a pendent rock,
> A forked mountain, a blue promontory
> With trees upon't that nod unto the world
> And mock our eyes with air.
> That which is now a horse, even with a thought,
> The rack dislimns and makes it indistinct
> As water is in water.

But whatever the cause, there was not, down the ages, until the very modern year 1801, any attempt whatever to classify the clouds, although from the beginning everybody everywhere talked about the weather and many wrote about it. This first attempt, made in 1801, as just stated, was by the French naturalist, Lamarck. It received little attention, however, and no general acceptance; owing in part, presumably, to the fact that it was expressed in the words and phrases of a distinctly local or national language unfamiliar to the world at large.

But the time for a practical classification of the clouds was ripe. The need for it was felt by the large number of educated and cultured people who were then taking an active and inquisitive interest in the weather and its ways. Hence in a little while another classification was proposed, this time, 1803, by the Englishman, Luke Howard. Like that of Lamarck's, it, too, was based on the *appearance* of the clouds, but the names, instead of being only locally understood, were all in tolerably familiar Latin—the Esperanto of the day. At any rate, whether this universal language had much to do with it or not, Howard's classification soon became well known and extensively used: so much so indeed that all subsequent practical classifications have been but extensions of this original one published in 1803, with the addition, perhaps, of a few unusual and,

commonly, unimportant types, some of which Howard probably never saw.

To obtain uniformity in the cloud reports of professional meteorologists, and of all others who wished to be clearly understood, the International Meteorological Committee published in 1910, with illustrations, the following definitions and descriptions of cloud forms. The inclosed letters next after each type name are its customary abbreviation. The illustrations are new (the original ones are not available) but quite as good and typical, it is hoped, as those selected by the committee.

The wording here followed of these international definitions and descriptions is not exactly that of the original publication, but that given in the second edition of "Cloud Forms," 1921, by the British Meteorological Office.

This latest classification of the clouds, a modification and extension of Howard's, is also, like it, based on mere *appearance* and not on anything really fundamental, such as cause or mode of formation. But however superficial such a classification may be, it nevertheless is the best, perhaps, that can be made, and altogether the most practical. For instance, the mode of origin is not a practical basis for cloud classification, however desirable, because several types of cloud are formed in different ways and frequently one can not be certain just what the actual way really was.

The supplementary remarks, after each of the following quoted definitions and descriptions, while intrusive in position, may, it is hoped, be of some service to those who are not yet cloud experts.

INTERNATIONAL DEFINITIONS AND DESCRIPTIONS OF CLOUD FORMS, AND SUPPLEMENTARY REMARKS.

1. Cirrus (Ci.)—"*Detached clouds of delicate appearance, fibrous (threadlike) structure, and featherlike form, generally white in color.* Cirrus clouds take the most varied shapes, such as isolated tufts of hair, *i. e.*, thin filaments on a blue sky, branched filaments in feathery form, straight or curved filaments ending in tufts (called *cirrus uncinus*), and others. Occasionally cirrus clouds are arranged in bands, which traverse part of the sky as arcs of great circles, and as an effect of perspective appear to converge at a point on the horizon and at the opposite point also, if they are sufficiently extended. Cirro-stratus and cirro-cumulus also are sometimes similarly arranged in long bands." (Pl. 2, fig. 2; pl. 3, figs. 1 and 2; and pl. 4.)

An interesting form of cirrus clouds is the familiar "mares' tails" (pl. 3, fig. 2), especially when a considerable number of them occur

in the same region of the sky. These are only thin streaks of snow into which a little ball of rising cloud is drawn out, partly by the slow descent of the snow itself, and partly by the increase of wind velocity with elevation.

The cirrus occurs up to (and usually at) greater heights than any other type of cloud—roughly 5 miles in polar regions, 7 in middle latitudes, and 9 within the Tropics. Since it occurs above all other clouds it also is the coldest, ranging, roughly, from 50°F. below zero near the poles to 90° below in the neighborhood of the Equator, the difference in temperature being due to the difference in height. Furthermore, because it is the coldest of the clouds it likewise is the thinnest, being formed in air whose water content, owing to its low temperature, must be very small. Indeed, the sun and moon are sharply outlined through it. Finally, as its temperature is so very low the cirrus nearly always (there seem to be occasional exceptions) consists of snow crystals.

As just stated, the cirrus occurs at higher levels than does any other type of cloud. But it also occurs, under favorable conditions, at any other level, even down to the surface. It is only a shallow, or thin, cloud of fine snow crystals (except rarely) drawn out by the wind into more or less parallel, fine streaks. Its chief cause appears to be the further cooling, by expansion due to ascent, of air already cold and holding but little moisture, and the dragging out of the slight cloud thus formed into streaks and whirls by the winds in which it occurs.

When the cirrus slowly disappears, leaving a clear sky, fair weather is probable for at least a day or two. On the other hand, when it gradually thickens and merges into a nearly continuous and formless sheet, rain or snow usually begins within a few hours.

2. Cirro-stratus (Ci.-St.).—"*A thin sheet of whitish cloud; sometimes covering the sky completely and merely giving it a milky appearance; it is then called cirro-nebula or cirrus haze; at other times presenting more or less distinctly a fibrous structure like a tangled web.* This sheet often produces halos round the sun or moon." (Pl. 5, fig. 2.)

The halos here referred to are of two kinds: (*a*) Those due to the refraction of light into rainbow colors on its passage through ice crystals; and (*b*) those produced by the mere reflection of light (hence white or colorless) by the faces of these crystals.

The most common of the first class of halos are: (1) The circle of 22° radius about the sun or moon (pl. 5, fig. 2); (2) the similar circle of 46° radius; and (3) the circumzenithal arc, a brilliantly colored arc having the point directly overhead as its center, but appearing on the side next the sun only. The chief halos of the second

or reflection class are (1) the parhelic circle, a white band of light passing around the sky parallel to the horizon and through the sun (pl. 5, fig. 2); and (2) the sun pillar, a vertical column of white light extending directly above and below the sun.

These halos are positive proof that the cirro-stratus clouds, like the cirrus from which they frequently are developed, also consist, normally, of myriads of ice crystals.

Whenever the cirro-stratus cloud (pl. 5, fig. 1) has developed from a cirrus it may be assumed that rain or snow, as determined by the temperature, probably will soon follow, not out of the cirro-stratus, of course, but from an approaching nimbus, or rain cloud.

Though denser than the cirrus, the cirro-stratus still is so thin as to leave the outline of the sun sharply defined.

3. Cirro-cumulus (Ci.-Cu.)—"*Mackerel Sky.—Small rounded masses or white flakes without shadow, or showing very slight shadow; arranged in groups and often in lines.* French, *Moutons*—German, *Schäfchen-wolken.*" (Pl. 6, figs. 1 and 2.)

The term "mackerel sky" is an abbreviation of "mackerel-back sky," so named because of the frequent resemblance of rows of cirro-cumuli to the patterns (not the scales) on the backs of one or more species of mackerel. When the cirro-cumuli are small, numerous, and without order or pattern, they often are called "curdle sky." (Pl. 6, fig. 2.)

All forms of the cirro-cumulus appear to be due to small local convections. Those occurring in rows presumably are on the crests of air waves or billows at the interface between wind layers of unequal speeds or different directions, or both, and commonly unequal also in temperature and humidity. The cirro-cumulus, through turbulence or other cause, often merges into a more or less uniform, stratified cloud, especially the cirro-stratus.

The fact that the cirro-cumuli cast but faint shadows, if any, and that the sharp outline of the sun is visible through them shows that they are quite thin and contain but little cloud material.

4. Alto-cumulus (A.-Cu).—"*Larger rounded masses, white or grayish, partially shaded, arranged in groups or lines, and often so crowded together in the middle region that the cloudlets join.* The separate masses are generally larger and more compact (resembling strato-cumulus) in the middle region of the group, but the denseness of the layer varies and sometimes is so attenuated that the individual masses assume the appearance of sheets or thin flakes of considerable extent with hardly any shading. At the margin of the group they form smaller cloudlets resembling those of cirro-cumulus. The cloudlets often group themselves in parallel lines, arranged in one or more directions." (Pl. 7, figs. 1 and 2; pl. 8, figs. 1 and 2; pl. 9, fig. 1.)

The alto-cumuli appear to be due to local convections, caused either by differences of temperature or by wave motion, analogous to those that produce the cirro-cumuli, but are at lower levels, roughly 2½ miles high, usually larger in volume and of more humid air, They frequently form in the early forenoon after a clear sunrise in consequence of scattered convection in a humid layer of air—humid from the evaporation in it of a previous sheet of alto-cumuli, or owing to moisture from the spreadout tops of thunderstorm clouds. After sundown this type of cloud frequently evaporates, through the process of cooling, contracting, and then sinking to a warmer and drier level.

5. Alto-stratus (A.-St.).—"*A dense sheet of a gray or bluish color, sometimes forming a compact mass of dull gray color and fibrous structure.* At other times the sheet is thin like the denser forms of cirro-stratus, and through it the sun and the moon may be seen dimly gleaming as through ground glass. This form exhibits all stages of transition between alto-stratus and cirro-stratus, but according to the measurements its normal altitude is about one-half of that of cirro-stratus." (Pl. 6, fig. 2; pl. 9, fig. 2.)

This type of cloud may be formed by the flow of warmer moist air over colder air beneath, by winds dragging out the tops of thunderstorm clouds, by the cooling in place of a layer of humid air, and by the relatively small precipitation out of alto-cumulus and cirro-cumulus.

The sun and moon when seen through the alto-stratus, alto-cumulus, or any other thin cloud of *water droplets*, are surrounded by one or more sets of rings of colored light commonly only two or three diameters of the sun, or moon, away (pl. 26, fig. 2).

These small circles, in which the red is farthest from the sun or moon are called coronae, and are produced, as just stated, by the action (diffraction) of small water droplets on the light. The much larger circles, called halos, and whose red portions are nearest the sun, or moon, are caused, as previously explained, by the passage of light through *ice crystals.*

6. Strato-cumulus (St.-Cu.).—"*Large lumpy masses or rolls of dull gray cloud, frequently covering the whole sky, especially in winter.* Generally strato-cumulus presents the appearance of a gray layer broken up into irregular masses and having on the margin smaller masses grouped in flocks like alto-cumulus. Sometimes this cloud-form has the characteristic appearance of great rolls of cloud arranged in parallel lines close together. (*Roll-cumulus* in England, *Wulst-cumulus* in Germany.) The rolls themselves are dense and dark, but in the intervening spaces the cloud is much lighter and blue sky may sometimes be seen through them.

Strato-cumulus may be distinguished from nimbus by its lumpy or rolling appearance, and by the fact that it does not generally tend to bring rain." (Pl. 10, figs. 1 and 2.)

This cloud, of which there are several forms ranging from the stratus of uneven density through the great parallel rolls to the sheet of well-nigh discrete cumuli, is always due to vertical convection. The more nearly discrete or separate masses are produced by the rising of warm air (thermal convection), while the irregularities in the stratus form appear to be caused, in large part at least, by mechanical turbulence. This last type (pl. 10, fig. 2), might well be called turbulo-cumulus. The shallow depth and broad expanse of the strato-cumulus often is due to an overlying layer of air of such temperature that the rising, cloud-laden column can not pass through it, and hence is forced to spread out, much as rising smoke in a room spreads out under the ceiling.

7. Nimbus (Nb.).—"*A dense layer of dark, shapeless cloud with ragged edges from which steady rain or snow usually falls. If there are openings in the cloud an upper layer of cirro-stratus or alto-stratus may almost invariably be seen through them.* If a layer of nimbus separates in strong wind into ragged cloud, or if small detached clouds are seen drifting underneath a large nimbus (the '*Scud*' of sailors), either may be specified as *fracto-nimbus* (Fr.-Nb.)" (Pl. 11, fig. 1.)

The name of this cloud has evoked much discussion. Nimbus, originally meaning cloud and, inferentially, storm, now means snow or rain cloud. Hence, many argue, if rain or snow is falling from a cloud it certainly is a rain cloud. Likewise, if rain is not falling from it, then clearly it must be some other sort of cloud. But, on the other hand, if a given cloud while raining happens to be a typical rain cloud (nimbus), what was it immediately before we saw the rain? Again, if it happens to be raining very hard what shall we call the cloud that we can not see for the rain? Suppose that we can not see the edge of the cloud that is raining, and generally we can not, dare we then call it a nimbus in face of the official definition "with ragged edges"?

These are typical of the questions and quibbles the arbitrary official definition of "nimbus" has evoked.

As a matter of fact a trace at least of precipitation may be falling from a typical alto-stratus, alto-cumulus, or other form, which it would be but confusion to call nimbus. Similarly, a typical nimbus from which rain is falling steadily looks but little different from what it did immediately before the rain began. Hence it is convenient to interpret the definition broadly enough to cover both cases. If the cloud is typically alto-cumulus, call it alto-

cumulus, whatever may be falling. On the other hand, if it looks like a rain cloud and is not a "cumulo-nimbus," described below, call it nimbus, whether it is raining or not and regardless of all edges.

Of course in taking weather notes it commonly is superfluous to say both rain and nimbus cloud, because the former nearly always implies the latter, except in the case of the thunderstorm, which is separately reported. However, if one were noting clouds alone he certainly should say nimbus, or occasionally, nimbus cumuliformis, whenever there is precipitation of appreciable intensity without lightning or thunder.

This type of cloud is most frequently formed by some kind of mechanical convection, such as ascent due to converging winds, the flow of air over mountain barriers, and the over and under running of currents of different temperatures.

The fracto-nimbus, or scud, is only a low, ragged detached fragment of cloud that often rises, like steam, immediately after rainfall on a warm surface, especially the sides of mountains, which it ascends like drifting fog. (Pl. 11, fig. 2.) It also is frequently dragged out of a crest cloud (which see below), by the swirls of the passing wind and hurled down the leeward mountain slope.

8. Cumulus (Cu.).—"*Woolpack or Cauliflower Cloud.—Thick cloud of which the upper surface is dome-shaped and exhibits protuberances while the base is generally horizontal.* These clouds appear to be formed by ascensional movement of air in the daytime which is almost always observable. When the cloud and the sun are on opposite sides of the observer, the surfaces facing the observer are more brilliant than the margins of the protuberances. When, on the contrary, it is on the same side of the observer as the sun it appears dark with bright edges. When the light falls sideways, as is usually the case, cumulus clouds show deep shadows." (Pl. 7, fig. 2; pl. 12, figs. 1 and 2; pl. 13, figs. 1 and 2; and pl. 14, fig. 1.)

"True cumulus has well-defined upper and lower margins; but one may sometimes see ragged clouds—like cumulus torn by strong wind—of which the detached portions are continually changing; to this form of cloud the name *fracto-cumulus* may be given." (Pl. 14, fig. 2.)

Even the most casual observation shows the cauliflower heads and sides of cumuli to be in a state of rapid change and constant turmoil. All clouds of this type are caused by the lower air being so much warmer than the upper that it is forced to ascend much as warm air is pushed up a chimney by the heavier cold air on the outside. Hence, even forest fires sometimes cause the formation of

cumuli. (Pl. 15, fig. 1.) However, we should remember that the fire itself adds a surprisingly large amount of moisture to the air—a gallon of water, roughly, for every 15 pounds of fuel burned, so that the fire cumulus is not entirely due to convection.

Since cumuli are caused by rising air currents induced by relatively high surface temperatures, they are very common in equatorial regions, and also through the middle latitudes during summer. Hence, too, they commonly occur over land most frequently during the afternoon and over water late at night. For the same reason they often follow a coast line over the water at night and over the land through the day. Similarly they are common over islands (pl. 15, fig. 2), whose presence frequently is shown in this way while they themselves are still below the horizon.

9. Cumulo-nimbus (Cu.-Nb.).—"*The thunder cloud; shower cloud.—Great masses of cloud rising in the form of mountains or towers or anvils, generally having a veil or screen of fibrous texture (false cirrus) at the top and at its base a cloud mass similar to nimbus.* From the base local showers of rain or snow, occasionally of hail or soft hail, usually fall. Sometimes the upper margins have the compact shape of cumulus or form massive heaps, around which floats delicate false cirrus. At other times the margins themselves are fringed with filaments similar to cirrus clouds. This last form is particularly common with spring showers. The front of a thunderstorm of wide extent is frequently in the form of a large low arch above a region of uniformly lighter sky." (Pl. 16, figs. 1 and 2.)

This is the most turbulent and also the thickest of all clouds, ranging in depth commonly from 1 to 3 miles, and occasionally, in tropical regions, even to 8 or 9 miles. Its times, places, and modes of occurrence are all the same as those of the cumulus, given above.

10. Stratus (St.).—"*A uniform layer of cloudlike fog not lying on the ground.* The cloud layer of stratus is always very low. If it is divided into ragged masses in a wind or by mountain tops it may be called *fracto-stratus.* The complete absence of detail of structure differentiates stratus from other aggregated forms of cloud." (Pl. 11, fig. 2.)

The stratus is the lowest of clouds, averaging around 2,000 feet above the surface. It frequently is formed by the lifting of relatively warm, humid air by underrunning cold winds; by the flow of a warm, humid wind over a surface stratum of cold air; and by the drifting of deep fog from the sea over relatively warm land, as in the case of the "velo" cloud of southern California, in which the lower portion of the fog is delightfully evaporated away, while the

upper part is left as a gracious veil that shields one from the sun until nearly noon.

The same pamphlet, entitled "Cloud Forms," from which the above quoted definitions and descriptions of the ten standard cloud types were taken, contains also the following instructions to observers:

"(*a*) In the daytime in summer all the lower clouds assume, as a rule, special forms more or less resembling cumulus. In such cases the observer may enter in his notes '*stratus-* or *nimbus-cumuliformis.*'

"(*b*) Sometimes a cloud will show a mammillated surface and the appearance should be noted under the name *mammato-cumulus.* (Pl. 17, fig. 1.)

"(*c*) The form taken by certain clouds particularly on days of sirocco, mistral, föhn, etc., which show an ovoid form with clean outlines and sometimes irisation, will be indicated by the name *lenticular*, for example: *Cumulus lenticularis*, *stratus lenticularis* (Cu.-lent., St.-lent.).

"(*d*) Notice should always be taken when the clouds seem motionless or if they move with very great velocity."

SPECIAL CLOUD FORMS.

It may seem, no doubt, that enough cloud forms have already been mentioned to include every type known to the heavens, and thus to satisfy the most ardent cloud observer, but, in addition to the gradual transformation of a cloud from one type to another, giving stages that puzzle the expert, there are several occasional forms sufficiently distinct, even though some of them belong to the general types already mentioned, to justify individual names and special descriptions.

Billow cloud.—Billow clouds (pl. 9, fig. 1), also called windrow clouds and wave clouds, occur in nearly equally spaced parallel bands, generally with intervening strips of clear sky. The billow cloud most frequently, perhaps, is only a special form of the more general alto-cumulus. It also is a common form, rather as ripples, however, of the cirro-cumulus (pl. 6, fig. 1). On rare occasions it likewise occurs at low levels where it might be called a type of strato-cumulus.

But whatever its level, the billow cloud is always produced in the same way—by the flowing of one stratum or current of air over another of distinctly greater density, thereby creating air billows precisely as water billows are formed on the ocean. Now, the

crests or tops of these waves are cooled by expansion, having risen above their previous level, and their troughs or bottoms warmed by compression. Hence, when the under layer is practically saturated, each crest, because of this cooling, is cloud-capped, and each trough clear.

It is particularly interesting to note that although each billow cloud maintains its identity and position in the series of waves as long as it exists at all—for hours it may be—nevertheless the actual particles of which it consists at any instant have only the briefest duration, there being continuous condensation on the rising or windward side of the billow and equivalent evaporation in the descending or leeward portion.

Furthermore, while the billow cloud progresses steadily across the sky, its velocity is neither that of the upper stratum nor of the lower, any more than the velocity of a water wave is either that of the wind that is producing it or of the water in which it occurs. Wind velocity, therefore, can not be determined by measurements on clouds of this kind; nor, of course, by attempted measurements on any of the stationary types, such as those mentioned below.

Lenticular cloud.—The lenticular cloud (pl. 17, fig. 2; pl. 18, figs. 1 and 2; pl. 19; and pl. 20, fig. 1) is only the cloud cap to a stationary or nearly stationary air billow produced as a rule by the flow of the wind over an uneven surface. It is especially common among high peaks and rugged mountains. Its material, like that of the crest cloud, is in rapid change—condensation on the windward side and evaporation to the leeward. Hence it is shaped like a double convex lens, the suggestive origin of its name, thickest in the middle and thinning away to nothing on either side.

As implied above, this is a stationary cloud, and hence one of the several that can not be used to measure wind velocities.

Crest cloud.—The crest cloud (pl. 20, fig. 2) is caused by the upward deflection, and consequent cooling by expansion, of humid winds by a long mountain ridge, whose crest it commonly covers, whence its name, and whose sides it often gracefully drapes. Occasionally, however, it forms slightly above and a trifle to the leeward of the ridge along the topmost (hence coolest) portion of the deflected wind current. In either case the cloud is permanent in position only, being continuously created (condensed) on the windward or ascending and cooling side, and destroyed (evaporated) on the lee or descending and warming side.

The best known example, perhaps, of this interesting cloud is the celebrated "Table Cloth" of Cape Town pride, spread by the southeasterlies over the top and down the sides of Table Mountain.

When the obstruction is only a peak the crest cloud is apt to be called a cap, hat, cowl, hood, and the like, all of which are recognized signs of bad weather, as, for instance:

"When Falkland Hill puts on his cap,
The Howe o' Fife will get a drap.

"When Traprain puts on his hat,
The Lothian lads may look to that.

"When Rubenslaw puts on his cowl,
The Dunion on his hood,
Then a' the wives of Teviotside
Ken there will be a flood."

Riffle cloud.—Very often the crest cloud along a mountain ridge is paralleled by a similar but smaller cloud over the leeward valley, or plain in the case of the exceptional isolated mountain. The wind, deflected in a great wave over the mountain, rises in a series of decreasing billows beyond, like the waves or riffles in a river due to a ledge of rock, or other obstruction, on the bottom—hence the name "riffle cloud."

The process by which the crest cloud is formed along the ridge of the mountain and restricted thereto, that is, the cooling of the air by ascent on the windward side and its warming by descent on the lee side, occurs also in the rising and falling air on the windward and the lee sides respectively of the series of air waves, or giant riffles, induced by the mountain obstruction to the wind. Hence, when the crest cloud is at all heavy the top of the first and largest wave is apt to be clouded; even the second wave occasionally shows some cloud, but the third rarely if ever.

The crest cloud and the riffle cloud, since they show the presence of humid winds, are excellent signs of rain, or snow, in a few hours. The order of occurrence is: Formation of the crest cloud; thickening of the crest cloud and forming of the riffle cloud; growth and union of these two clouds and the complete covering of the sky; onset of rain or snow.

Banner cloud.—The banner cloud (pl. 21, fig. 1) suggests a great white flag, whence its name, floating from a tall mountain peak. In strong winds the atmospheric pressure to the immediate leeward of such a peak is more or less reduced. If the humidity is right this causes a cloud through the resulting cooling, aided, no doubt, in many cases, by the cold walls of the peak itself. Here too, as in the preceding cases, the cloud is stationary, but its substance in rapid flux through condensation on one side and evaporation on the other.

Scarf cloud.—It occasionally happens that as a cumulus rises rapidly to a great height a thin cirrus-like cloud arch, convex upward, forms above, and detached from, the topmost cumulus head (pl. 21, fig. 2), so suggestive of a halo as to arouse poetic if not even pious fancies. As the cumulus continues to rise this flossy cloud grows and rests like a veil over the thunderhead. A little later, a few minutes at most, it mantles the cumulus shoulder (pl. 22, fig. 1), the head or heads being free, and may even drape the sides. In all cases it has the sheen and apparent texture of a great silken scarf—hence the name. It has often been called false cirrus, but that term is now commonly restricted to an entirely different cloud. It frequently is also called a cap cloud, but this name, apart from being loosely applied to any sort of cloud on a mountain peak, is applicable, by analogy, only during the early stages of the development of the scarf cloud and hence neither distinctive nor properly descriptive.

It is caused by the rising and consequent expansion and cooling of the air directly above the cumulus heads. Ordinarily this movement and cooling of the air over the cumulus produces no visible effect. Occasionally, however, there happens to be a stratum of air at a considerable height (3 or 4 miles) that is practically saturated. When such a layer is lifted locally, as just explained, a thin cloud, the first stage of the scarf cloud, is formed at the place of disturbance. When this layer is thin, as it commonly is, the thunderheads generally pass quite through it into drier air above, leaving the scarf cloud mantling the shoulders of the cumulus, or draping its sides at about the original level of the humid stratum.

Although this is not a rare cloud, few, apparently, are familiar with it, owing to its ephemeral nature and occurrence with other clouds. It has, of course, but little of the grandeur of a towering cumulus or intricacy of a far-flung cirrus, nevertheless, its coming into existence at an unexpected place, its silken texture, and its changes in form and position all merit its being carefully looked for and closely followed when found.

Tonitro-cirrus.—The name "tonitro-cirrus," thunder cirrus, is applied to those gray locks, to speak figuratively, combed out from old thunderheads by the upper winds, and also the thinner edges of the *anvil cloud*, or spreading top of a cumulo-nimbus. (Pl. 22, fig. 2.)

Even though the winds of the lower atmosphere are always light when great towering cumuli are formed, the upper winds may still be strong. Clearly, then, the top of a cumulus that extends into a stratum of swift winds is certain to be drawn out into a more or less extensive, fibrous sheet of snow crystals that differs but little, if any, from the ordinary cirrus except in its mode of origin. A more common name for this cloud is "false cirrus,' but this term

is objectionable since the cloud in question is indeed a cirrus, differing from other cirri, as stated, only in origin.

Mammato-cumulus.—The mammato-cumulus, called also pocky-cloud, festoon-cloud, sack-cloud, "rain balls," and several other local names, is a sort of miniature up-side-down cumulus. (Pl. 17, fig. 1.) It occurs most frequently in connection with severe thunderstorms, and appears to be due to irregular descents here and there of cold air onto an existing stratus cloud, each place of fall being marked by a downward bulge in the cloud base.

Tornado or funnel cloud.—The tornado or funnel cloud (pl. 23, figs. 1 and 2; pl. 24) is only a long funnel-shaped cloud about the axis of rotation of a tornado. It hangs down, either straight or curved, from the base of a rain cloud—commonly, if not always, a cumulo-nimbus—and varies in extent all the way from a mere protuberance on the parent cloud, to a crooked trunk reaching all the way to the earth. It is caused by the cooling, due to expansion, of the rotating air, to a temperature below the dew-point. In short, it is just cloud, induced, like other clouds, by cooling, though often mixed with dust in its lower portion.

CLOUD MISCELLANY.

CLOUD MATERIAL.

Clouds consist either of water droplets, always when the temperature is above freezing, or ice crystals, normally when the temperature is below freezing, but not invariably, because occasionally the droplets cool without solidifying to, or, perhaps, form at, temperatures far below the "freezing point."

The droplets that together constitute a cloud out of which no rain is falling vary in size from the vanishingly small, especially at the surface and edges where they are likely to be disappearing by evaporation, or coming into existence through condensation, up to several fold that of the average particle. Most of them, however, appear to be about one one-thousandth of an inch in diameter, roughly the size of the familiar lycopodium spore. In rain clouds, on the other hand, such as the cumulo-nimbus, this range is much greater—from the invisibly minute, as before, up to the fully developed drop of one-tenth, say, to one-fifth (the maximum possible) of an inch across.

The ice crystals, the material of cold clouds, also vary widely in size, and include every gradation from the minute, almost microscopic, needles of the cirrus to the well-known snow flakes of the winter storm. Their chief claim, however, on our attention is not because of this interesting dimensional range, but owing to their

exquisite beauty. The fundamental pattern, however simple or complex the crystal, is always the same, the hexagon, or six-sided column, but the variety is endless: Needles with pyramidal ends; columns, with flat ends; mere hexagonal flakes; hexagons with a simple extension at each angle, and hexagons with complex extensions in myriad varieties—and all are beautiful. Naturally then, hundreds of these numberless forms, as admirably photographed by that enthusiast, Mr. W. A. Bentley, of Jericho, Vt., have been used as models in design and art. Nor is there a keener zest than Mr. Bentley's as year after year he adds pattern upon pattern to his long since marvelous collection of photomicrographs of the snow crystal.

WHY THE ATMOSPHERE AS A WHOLE NEVER IS SATURATED.

Since evaporation is continuous from much the greater portion of the surface of the earth, it would seem that the atmosphere would soon become saturated throughout, and perhaps even filled everywhere with fog and cloud. But before the surface air has become approximately saturated to any considerable depth it commonly is carried to higher levels by some type of convection, and this causes it to cool, as already explained, and eventually to give up much of its moisture, generally in the condition of rain or snow. Sooner or later, however, the air out of which the precipitation falls returns to lower levels where clearly it is less humid, on the average, than when it began to ascend, by the amount of water abandoned during its upward course. In short, vertical convection induces precipitation through cooling, and precipitation in turn so dries the air as to prevent it from becoming and remaining everywhere intolerably humid, as it otherwise would be.

WHY CLOUDS FLOAT.

Since water is about 800 times heavier than air, one might well wonder how it is possible for a cloud, consisting of myriads of droplets, to float in a medium so light and of such slight resistance to penetration as the atmosphere. But, however imperceptible and entirely negligible the resistance of still air may be to our own movements, it is not strictly zero. In vacuo, for instance, as we know from one of the most familiar of experiments, "the farthing and the feather fall together," but more and more apart in air of increasing density. Now the total pull of a raindrop, say, causing it to fall, remains the same no matter how finely it is divided, while the amount of air disturbed, and hence the resistance and time of fall, increase with every subdivision; and since a single raindrop, one-sixth of an inch in diameter, is divisible into, or is the equivalent of, 8,000,000 average cloud droplets, it is clear that, while the rain

may descend, the cloud must settle, if it comes down at all, much more slowly.

Cloud droplets of the size just implied—that is, such that 1,200 of them side by side make a row 1 inch long—do, as a matter of fact, fall through still air about 8 feet per minute. Hence, where there are no rising currents, a cloud must, and does, gradually sink into the lower unsaturated air and evaporate. Clouds, however, as explained above, commonly are formed in ascending currents, and this ascent generally is distinctly greater than 8 feet per minute, the rate just given of cloudfall in still air. Hence cloud is continously formed at that level at which the rising air is cooled by its expansion to the dew point. The droplets here formed are carried to higher levels, there evaporated or merged into raindrops, or carried away, as circumstances determine, but new droplets replacing these are as continuously being formed as fresh humid air rises to the cloud level.

Clouds, therefore, do not even eventually fall to the earth because either they are continuously formed at the condensation level by rising currents or, on slowly sinking (8 feet per minute) to lower levels in still air, or being dragged down by descending air, are soon evaporated. In any case the cloud floats at a greater or less height and never falls precipitately to the earth as does rain.

HOW RAIN IS PRODUCED.

Few people ever ask how rain is produced. Perhaps this is because the phenomenon is too familiar to arouse one's curiosity or make him in the least inquisitive. Nevertheless, and however childish it may seem, it is both a rational question and a difficult one to answer.

The familiar, pretended answer, is, in effect, that somehow the air is cooled until condensation occurs on the various nuclei present, and that the larger of the droplets thus produced that happen to be well up in the cloud fall to lower levels, thereby encountering many other particles and through coalescence with them growing into full-sized drops. But, as implied, this explanation explains nothing. In the first place there are so many nuclei present in the atmosphere—hundreds at least, and usually thousands, to every cubic inch—that division of the condensed vapor between them leaves every one quite too minute to fall with any considerable velocity. Then, too, calculation shows that if a particle should fall, in the manner supposed, through a cloud even a mile thick and pick up everything in its path it still would be a small drop. That is, rain is not formed in this

simple manner, as is also obvious from the fact that a cloud may last for many hours without giving any rain whatever.

The actual processes in the formation of rain seem to be:

1. For some reason, such as surface heating, a mountain in the wind's path, or convergence of different currents, the surface air is forced up to considerable heights; during which rise it does work—gives up energy—by expansion against the surrounding pressure and thereby cools.

2. As soon as the dew point is passed condensation begins on the innumerable nuclei present and a cloud is formed, the particles of which, being heavier than equal volumes of air, slowly fall with reference to the atmosphere itself. That is, the rising current passes by the cloud particles to a greater or less extent however high they may be carried.

3. The lower cloud particles filter the air rising through them and thereby more or less clean it of dust motes and other nuclei. Hence the droplets formed in the rising air after this filtration grow much faster, being relatively few, than they otherwise would.

4. Presently many of the larger droplets coalesce and thus become heavy enough to fall against the rising current. Nor, indeed, can they fall (reach lower levels) until by condensation, or coalescence, or both, they have attained a certain minimum size determined by the vertical velocity of the air in which they happen to be.

In short, a rising current, essential to any considerable condensation, that sustains, or even carries higher, cloud droplets until they have grown to falling size, and the automatic filtering of the ascending air by the cloud formed in it (which filtering restricts further condensation to comparatively few particles and thus insures their rapid growth), appear to be necessary and sufficient to account for the formation of rain.

5. Most of the drops, as they emerge from a cloud, are likely to have substantially the same size, namely, that which is just sufficient to overcome the upward movement of the air in which they were formed. Now, drops of the same size fall with the same speed, hence any two that happen to be close together are likely to remain so much longer than drops of unequal size and thereby have more chances of union through fortuitous disturbances. Furthermore, when falling drops are side by side the air tends to push them together just as passing boats are forced toward each other. Clearly, though, this pressure has time to bring closely neighboring drops into actual contact only when they fall with the same or very nearly the same speed. From these considerations it seems that the smallest drops, size 1, say, should unite to form size 2, and size 2 unite with each other to form size 4, rather than with size 1 to form size 3,

and so on, doubling at each union. Hence we should expect more drops having the weights 1, 2, 4, 8, ... than any intermediate values, and this expectation has been fully verified by observations on all sorts of rains.

THE MEASURING OF CLOUD HEIGHTS.

It is always interesting and sometimes very useful to know the heights of the clouds, or, to be more exact, the heights of their bases—useful, frequently, to the aviator to whom very low clouds may be a danger and certainly a nuisance, and useful as an aid in forecasting the local weather for the next few hours.

There are several methods of determining the heights of clouds as accurately as ever is necessary. Indeed, under favorable circumstances, the error may not be more than a few feet.

1. The aviator, for instance, can take the reading, corrected if necessary, of his altimeter the instant he climbs into the base of a cloud.

2. A pilot balloon (small free balloon without instruments) may be observed from two stations a mile, say, apart, and its exact direction from each station, both horizontal and vertical, noted as it disappears into a cloud base. From these directions, which can be determined very accurately with suitable theodolites, and from the known distance between the two observing stations and the height of either above the other, the cloud height is readily obtained by a simple trigonometrical calculation.

3. Any definite spot on the base of a cloud may be simultaneously observed (triangulated, to be exact) from two stations and its height calculated from the data thus obtained, precisely as in the case of the pilot balloon. The observations, of course, may be either visual or photographic; the latter, if well done, generally being the better since it affords opportunity for detailed study and independent measurements on many different points.

4. The angular altitude of a kite and the length of wire out, at the time it enters a cloud base, also furnish a fair means of computing the desired height.

5. The exact time of disappearance of a kite up into a cloud may be noted, and the height of the kite at that instant, and hence also of the cloud, determined by subsequent examination of the temperature and pressure records on the kite instruments.

6. The level of storm clouds, or low clouds at the time of strong winds, and of ordinary cumuli, can be tolerably closely computed from the current values of the temperature and humidity.

The above are by no means all the possible ways of measuring the heights of clouds, but they are the more accurate and the ones most commonly practiced.

WHY THE BASE OF A GIVEN CLOUD, OR CLOUD SYSTEM, HAS EVERYWHERE NEARLY THE SAME HEIGHT.

One of the most interesting and significant things learned from cloud measurements is the fact that the base of any cloud sheet—that is, a particular sheet at a particular time, whether continuous or broken and scattered—is everywhere at about the same level. The reasons for this are very simple: (*a*) Since the temperature and humidity of the air at any given time are nearly the same at neighboring places over a considerable area, the height throughout such region is approximately constant at which rising air will have cooled to the dew point and cloud begun to form. Hence the base levels of a series of detached cumulus clouds are about the same. (*b*) Since rising air ascends until by expansion it has cooled to the temperature of the then surrounding air, at which level it spreads out and drifts away with the general circulation, and as convection, whatever its cause, applies to air of all degrees of humidity, and occurs at different times and all manner of places, it follows that the atmosphere is always more or less stratified in respect to its water vapor. In general, therefore, clouds must also form in these layers. There may be, and often are, two or more cloud layers at the same time at different levels, but a cloud filling the whole depth of the atmosphere, or even a layer 5 or 6 miles thick, is not to be expected, nor is any such layer of considerable extent often, if ever, formed.

LEVELS OF MAXIMUM CLOUDINESS.

Since several types of clouds occur at various elevations, and since no level, from the surface of the earth up to the highest cirrus, is free from condensation, it might seem that clouds are as likely to have one height as another throughout their possible range. However, it is certain that there are levels of maximum and minimum cloud frequency, even though it may not be as easy to prove some of them by direct observation owing to the prevalence of lower clouds. The more important levels of maximum cloudiness are:

Fog level.—As every one knows, a fog, whatever its depth, from a mere gauzy veil to the deepest and densest layer, is a cloud on the earth. Obviously, therefore, the surface of the earth itself is a level of maximum cloudiness.

Cumulus level.—Since evaporation tends all the time to saturate the atmosphere, and since humidity is held down by convectional condensation, and, further, since, over extensive areas, convection is roughly the same most of the time through an entire season, it follows that the ordinary rain cloud, and the common cumulus cloud, must have a roughly standard base level at a moderate elevation.

This level, therefore, say, 4,000 feet above the surface, is also a level of maximum cloudiness.

Alto-cumulus level.—The strong convection common to dry summer weather often produces small cumulus clouds at considerable heights— frequently 2 to 2½ miles above the surface. Furthermore, during the average thunderstorm a great deal of humidity is urged up to roughly this same level, and there spread out into a wide layer by the swifter winds of that height. Subsequent convections in this layer often induce many small cumuli. For both reasons, therefore, this level, known as the alto-cumulus level, is likewise one of maximum frequency of cloud.

Cirro-stratus level.—The topmost portions of the clouds in a cyclonic, or general, rain are carried forward over very extensive areas by probably the swiftest winds of the entire atmosphere. Hence this level, roughly 5 miles above the surface, is also one of maximum cloud frequency, or at least of cloud observation.

Cirrus level.—Rising masses of air can not ascend, for reasons well known, beyond the level of the highest cirrus clouds: that is, in middle latitudes, above an elevation of about 6 miles. Any air that reaches this level necessarily spreads out in an extensive sheet or layer in which, under favorable conditions, condensation occurs in the form of fine snow crystals. Hence this ultimate level of the ascending air, at which its horizontal spread is great, is also one of maximum cloud extent.

LEVELS OF MINIMUM CLOUDINESS.

If there are different levels of maximum cloudiness, it follows that between each two such adjacent levels there must be a level of minimum cloudiness. However, there is nothing of particular interest about any of these intermediate levels.

Why there are no clouds above the high cirrus.—The region above the high cirrus also is one of minimum cloudiness. In fact clouds do not occur in that region at all, and the reason is as follows:

There clearly is some temperature (actually about 60° F. below zero) at which each portion of the high atmosphere must lose as much heat by radiation as it gains, and this is the lowest temperature to which the free air can cool. This temperature is reached, in middle latitudes, at about 6 to 7 miles above sea level. Hence this is the limit of vertical convection—for higher convection would mean lower temperatures—and the maximum height, therefore, to which water vapor is carried. Of course some water vapor reaches greater heights by the slow process of diffusion, but all of this region is subject to frequent temperature changes just as is the

lower atmosphere, hence as soon as any appreciable amount of vapor diffuses to a higher level than that of the average cirrus it is frozen out in invisibly small amounts and the whole of the upper air thereby kept too dry for the formation of even the thinnest clouds.

RELATION OF CLOUD HEIGHTS TO SEASON.

Clouds generally are lower during winter than during summer. This is because the relative humidity is higher, or the atmosphere more nearly saturated, during the colder season than during the warmer. And this condition, in turn, is owing largely to the fact that vertical convection, which is the chief cause of rain and hence the chief drying agency of the air, is most active during summer, when the surface of the earth is strongly heated.

RELATION OF CLOUD HEIGHTS TO LATITUDE.

Just as clouds generally are higher in summer and lower in winter, so, too, and for the same reason, clouds commonly are highest in equatorial regions and gradually descend with increase of latitude to their lowest level in polar regions.

RELATION OF TYPE OF CLOUD TO THE SEASON.

As just explained, vertical convection, which is due largely to surface heating, is much stronger during summer than during winter. Hence the cumulus or woolpack cloud, a product of local convection, is characteristic of warm summer days, while the low stratus or layer cloud is equally characteristic of the winter season.

RELATION OF TYPE OF CLOUD TO LATITUDE.

For the same reason that the prevailing type of cloud varies with the season, it also varies with latitude. That is, in tropical regions, where vertical convection is strong, the cumulus cloud is very common, whereas, in the high latitude regions, where convection is feeble, it is unusual. Here the prevailing cloud is of the stratus or layer type.

CLOUD THICKNESS.

The thickness of clouds varies from all but zero in the case of faint cirrus, and vanishing wisps and flecks of any other type, up to the 10 miles or more of the deepest tropical cumulus. Habitually, however, the high cirrus, only a few hundred feet thick, is the thinnest of clouds; the cumulus, especially when the seat of a hail storm, is the thickest—often several miles deep. The common nim-

bus cloud, from which rain often falls all day, varies in thickness from, say, 500 feet, up to 4 or 5 miles. Its average thickness, however, appears to be, roughly, half a mile. All other types of clouds generally are intermediate in thickness between the cirrus and the nimbus, averaging, perhaps, 500 to 1,500 feet.

CLOUD VELOCITY.

The direction and speed of travel of clouds can be determined in several ways, most of which involve triangulation of the kind used by surveyors and geologists. In the great majority of cases the velocity of a cloud is that of the air in which it happens to be. In a few cases, however, the movement of the cloud is not that of its enveloping atmosphere. Thus the cloud that forms along the crest of a mountain is as stationary as a waterfall, and, like the waterfall, is continually renewed by fresh material. No matter how swift the current, the fall remains fixed, and however strong the wind over the mountain, cloud is formed in it as soon as it reaches a particular altitude, determined by the humidity and temperature, and evaporated as it is drifted beyond and to lower levels. The crest cloud, therefore, being always stationary, can not be used in measuring wind velocity. Neither can the riffle cloud, the lenticular cloud, nor the banner cloud, and for the same reason—all except certain kinds of the lenticular, are stationary whatever the wind velocity.

Neither can the velocity of the wind be determined by the movement of the parallel rolls of the windrow or billow cloud. These clouds rest on the crests of air waves which are caused by the flow of one wind sheet over another. The velocity of these waves, and, hence, of the clouds that crest them, is intermediate between that of the two sheets and therefore does not measure the actual velocity of either.

In the great majority of cases, though—that is, with the above exceptions—clouds do move strictly with the enveloping air. Hence, though everywhere blowing, in the course of time, from all directions—"boxing the compass," as the mariner says—in the Tropics they are nearly always from easterly points, northeast to southeast, and in middle latitudes prevailingly from westerly regions.

Their average velocity *when moving in their prevailing direction* increases with height at approximately the same proportion that the density of the atmosphere decreases—that is, at such a rate that the product of the velocity (cloud or wind) by the density of the air is a constant.

VARIATION OF CLOUDINESS WITH LATITUDE.

As is well known, the amount of cloudiness varies greatly in different parts of the world. In some places it would be perfectly safe, following the example of the Yuma Hotel, to advertise free meals for every day the sun does not shine, and equally safe in others to make a similar offer for every whole day that it does. Apart from such obvious causes of cloud variation as direction of the wind, particularly onshore and offshore, elevation, temperature, etc., there is also a well-marked latitude effect. Thus, in the equatorial regions, where convection is most active, nearly 60 per cent, on the average, of the sky is clouded; around latitude 30°, both north and south, or along the great belts of high pressure and over the principal arid regions the average cloudiness falls to the minimum value of 40 to 45 per cent, while in the neighborhood of the polar regions it becomes 60 to 75 per cent. All these are only average values for the respective latitudes. The cloudiness of individual places covers a much wider variation.

CLOUD SPLENDORS.

Crepuscular rays.—Everyone is familiar with the beautiful phenomenon of the "sun drawing water" (pl. 25, fig. 1)—sunbeams, that, finding their way through rifts in the clouds, are rendered luminous by the dust in their paths. Many people seem to consider this splendor an excellent weather sign, some insisting that it foretells rain, while others as strongly claim it indicates continued fair. As a matter of fact, it has no significance either way, hence its excellence as a bone of contention.

When there are a number of such rifts the beams of light seem to radiate from the sun like spokes from the hub of a great wheel, or like ribs from the pivot of a giant fan. However, they are practically parallel, for the sun, from which they all come, is 93,000,000 miles away. The seeming divergence is only a perspective illusion, the same as that which makes any long, straight, parallel lines—such, for instance, as the rails on a straight, level track of railway—appear to come closer and closer together with increase of distance.

Lightning.—Few things in all nature so widely range our sensibilities, from thrills of joy over the exquisitely beautiful to abject terror in the face of imminent death, as does the lightning's flash from the heart of the thundercloud.

The story of this wonder meteor—how Franklin showed it to be a form of electric discharge; how, as explained by Simpson, charge after charge is obtained within the cloud; what curious freaks it plays and marvelous things it does—is delightful in every detail

but far too long to include here; for, after all, lightning, whatever its interest and importance, is only a cloud incident.

When the storm is close by it is easy to see that lightning consists of one or more sinuous (not zigzag, as the artist paints it) lines or streaks of vivid white or pink. (Pl. 25, fig. 2.) Often there is one main trunk with a number of branches, all occurring at the same instant, while at other times there are two or more simultaneous disconnected streaks. Frequently the discharge, instead of being all at once, continues flickering and, on rare occasions, even stationary, like a glowing wire, during a whole second or more.

The rainbow.—Unlike the phenomenon of lightning, the rainbow is all beauty and splendor, with nothing whatever of the appalling—save alone to the physicist who undertakes to explain fully and clearly its every detail, a most difficult task. Perhaps this assertion may seem strange when so many textbooks, even some that are quite elementary, profess to explain the rainbow so simply that a child can understand it. But in this particular nearly all these books have the same fault—they "explain" beautifully that which does not occur and leave unexplained that which does.

The ordinary rainbow seen in a sheet of water drops—rain, spray, fog—is a group of circular or nearly circular arcs of colors whose common center is on the extension, in the direction of the observer's shadow, of the straight line connecting his eye with the luminous source, which, as everyone knows, is nearly always the sun, but not quite, for once in a while the moon, too, produces a very pretty bow.

Frequently there are two entirely different bows. The inner one, known as the *primary*, with red outer border of about 42° radius, and blue to violet inner border, is much brighter than the larger, or *secondary* bow, of about 50° inner radius, and whose colors occur in the reverse order of those of the primary bow. In addition to these two conspicuous bows one can often see from one to, rarely, half a dozen parallel, colored arcs just inside the primary bow, and a smaller number just outside the secondary bow. These are known as the *supernumerary* bows. Most of these phenomena are shown in plate 26, figure 1, copied, by kind permission, from a remarkably fine picture taken by Mr. G. A. Clarke, of Aberdeen, Scotland.

A careful observer will soon see that there is less light (that the clouds look darker) between the two bows than outside the secondary or within the primary; that the colors seen are not always the same; that the band of any given color varies in angular width, even, occasionally, from place to place in the same bow; and that the purity of the colors varies from time to time. As one would naturally suspect, all, or nearly all, these differences depend on the

size of the droplets. The greatest contrast, perhaps, is between the brilliant rainbow of the retreating shower and that ill-defined, faintly tinged bow one sometimes sees on a sheet of fog.

The halo.—As must be obvious to anyone, the cirrus and other very cold clouds nearly always consist of ice crystals. These reflect some of the light that falls upon them; and some of it they transmit, bent, or refracted, as we say, out of its course and split up into all its colors, but always with the red nearest to the source of light. Both the refracted and the reflected light produce various bright patterns properly known as halos.

By refraction we get: The very common ring of 22° radius about the sun or moon (pl. 5, fig. 2); the less frequent ring of 46° radius; the occasional brilliantly colored arc that has its center directly overhead and its convex side next to the sun; and rarely, numerous other splotches and arcs, all more or less distinctly colored, and things of beauty and interest.

By reflection, on the other hand, we get only white or colorless figures; chiefly, the parhelic circle (pl. 5, fig. 2) that passes through the sun and is parallel to the horizon; and a pillar of light that rises straight up through the sun, much as would its reflection in rippled water if stood on end.

The corona.—Thin clouds of water droplets also produce beautiful colored rings about the sun and moon, but usually much smaller than the circles formed by refraction through snow crystals, and with their colors in reverse order; that is, with the red farthest from the source of light instead of nearest to it. These rings, known as coronas, are owing to what the physicist calls diffraction, or, in this case, the bending of the light around the droplets into their shadows. They are most frequently seen about the moon, but may be seen even more brilliantly, occasionally in a widening series of two or three repetitions of the colors, about the sun, if one will use dark glasses to cut down the glare.

Plate 26, figure 2, from a drawing by Mr. G. A. Clarke, of Aberdeen, Scotland, shows a magnificent corona and also contains other phenomena observed by him at that place on June 13, 1921. These were: (*a*) The slightly veiled image of the sun; (*b*) an aureole of faintly colored light close to the sun; (*c*) a triple corona in which the radii of the red or outer borders of the three rings were about 6°, 10°, and 16°, respectively; (*d*) iridescence (see below) merged with and extending beyond a portion of the outer coronal ring; (*e*) portions of a fine halo of 22° radius, produced by a background of thin cirro-stratus.

Cloud iridescence.—Unquestionably the most beautiful thing in all the heavens is a magnificent display of iridescent clouds—numerous

splotches among the cirro-cumuli, or other high type, and borders of thin lenticular alto-strati and alto-cumuli, of gorgeous opalescent rose pinks, emerald greens, and other colors, randomly mixed and covering a large part of the sky 15° to 30° from the sun.

It can be fully explained (being only fragments of giant coronas due to unusually small droplets), but only in the language of the physicist and symbols of the mathematician. Its beauty, however, can be enjoyed by all, and whoever looks at the heavens for anything should watch most frequently and carefully for the glorious apparition of the iridescent cloud.

CLOUDS AS WEATHER SIGNS.

Since the height, extent, and shape of clouds depend upon the humidity, temperature, and motion of the atmosphere, it is obvious that they often may furnish helpful hints of the coming weather. Thus, thin cirrus clouds, when not increasing in extent nor growing denser, indicate fair weather for at least 24 hours; and the same is true of the alto-cumuli. In general

"The higher the clouds, the finer the weather."

On the other hand, when the cirrus grows denser, and when the sky is covered with cirro-cumuli, rain within 24 hours is likely.

"Mackerel scales and mares' tails
Make lofty ships carry low sails."

Also, when large cumuli develop in the forenoon, there probably will be local thundershowers in the afternoon.

"In the morning mountains,
In the evening fountains."

Again, when two or more layers of cloud are moving in different directions, foul weather is almost certain to occur very soon. In short, if one may coin a "proverb,"

Whene'er the clouds do weave
'Twill storm before they leave.

Clouds of the lower and intermediate levels from north to west usually imply fair weather for a day or two; clouds from east to south generally mean rain within 24 hours. (This is for most of the temperate regions of the Northern Hemisphere; for the Southern Hemisphere, write north for south and south for north.)

"When the carry [current of clouds] goes west,
Gude weather is past;
When the carry goes east
Gude weather comes nest."

Fog clearing up early means a fair day; fog persisting implies that there probably will be rain later in the day, or during the coming night. As the proverb puts it:

"Mists dispersing on the plain
Scatter away the clouds and rain;
But when they hang on the mountain tops
They'll soon descend in copious drops."

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1. RADIATION FOG, LOUDOUN VALLEY, VA.

(A. J. Weed, photo.)

2. ADVECTION FOG, SEEN FROM MOUNT WILSON, CALIF.

(F. Ellerman, photo.)

1. ADVECTION FOG, SEEN FROM MOUNT WILSON, CALIF.

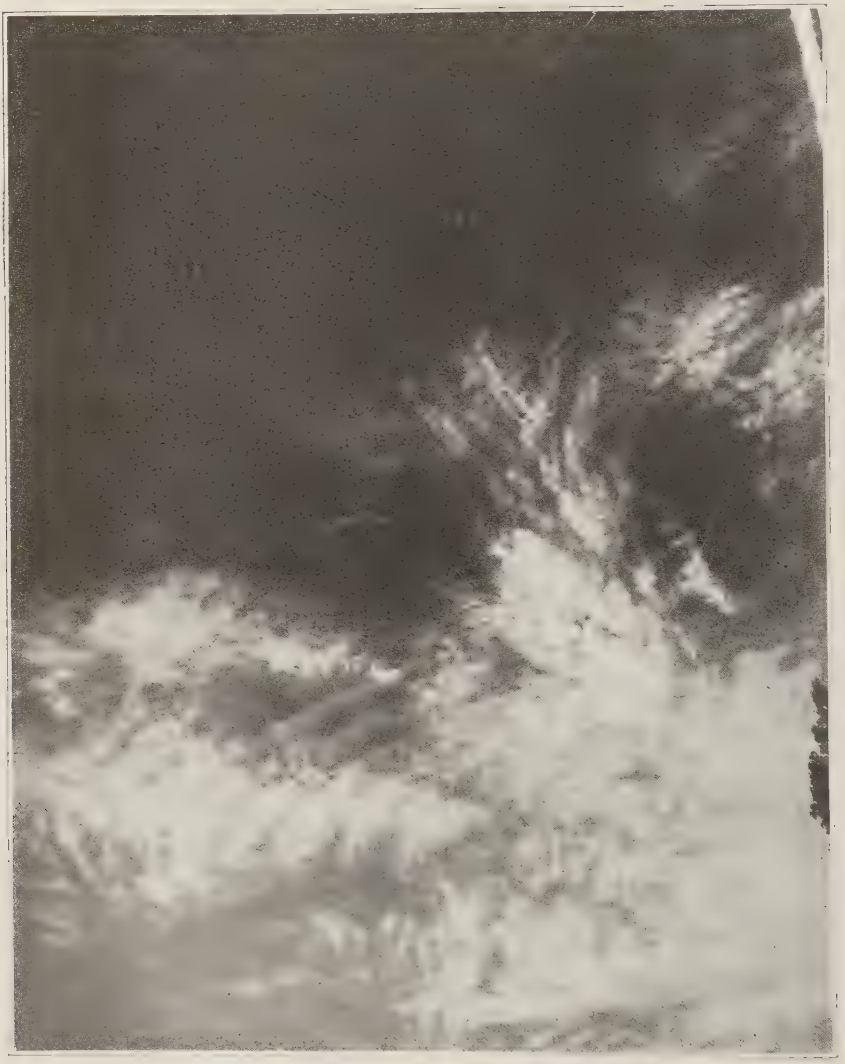
(F. Ellerman, photo.)

2. CIRRUS.

(F. Ellerman, photo.)

1. CIRRUS.
(F. Ellerman, photo.)

2. CIRRUS.
(F. Ellerman, photo.)

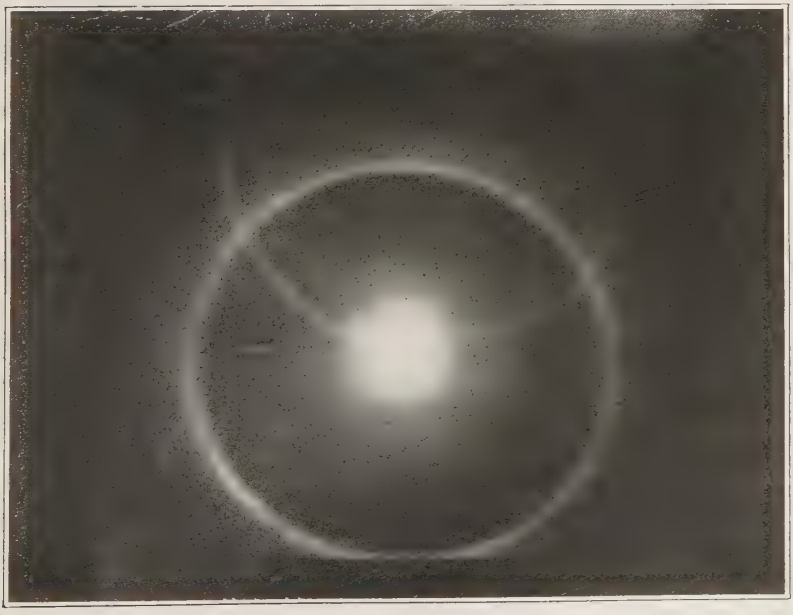


CIRRUS, MERGING INTO CIRRO-CUMULUS.

(F. Ellerman, photo.)

1. CIRRO-STRATUS ABOVE, ADVECTION FOG BELOW; SEEN FROM MOUNT WILSON, CALIF.

(F. Ellerman, photo.)



2. HALO OF 22° AND PARHELIC CIRCLES.

(Contributed by A. M. Comey.)

1. CIRRO-CUMULUS.
(E. E. Barnard, photo.)

2. CIRRO-CUMULUS, WITH ALTO-CUMULUS MERGING INTO ALTO-STRATUS TO THE LEFT, FROM THE EBRO OBSERVATORY, TORTOSO, SPAIN.

1. ALTO-CUMULUS, SEEN FROM MOUNT WILSON, CALIF.

(F. Ellerman, photo.)

2. ALTO-CUMULUS, TURRETED, AND CUMULUS; SEEN FROM MOUNT WILSON, CALIF.

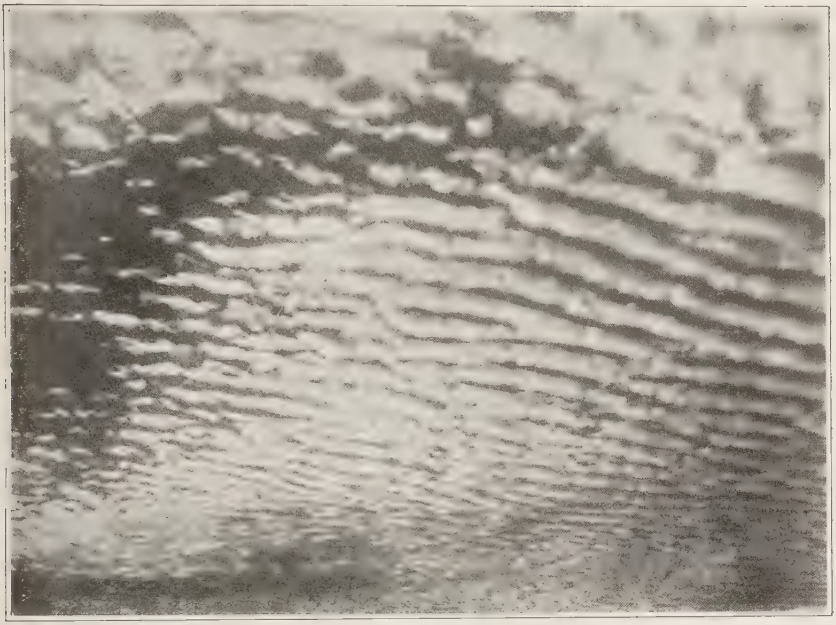
(F. Ellerman, photo.)

1. ALTO-CUMULUS.

(A. J. Weed photo.)

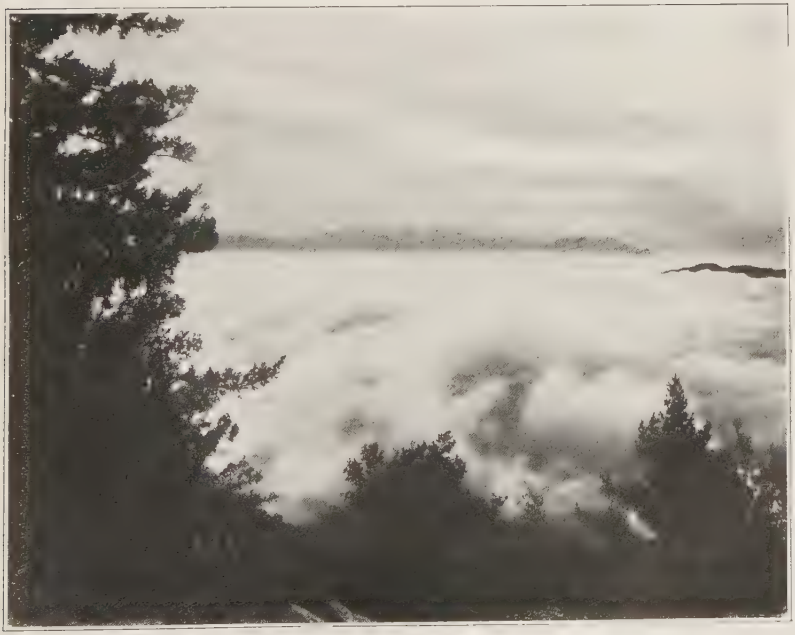
2. BILLOW CLOUDS, REGULAR AND IRREGULAR (FORMS OF ALTO-CUMULUS), OVER WASHINGTON, D. C.

(A. J. Henry, photo.)



1. BILLOW CLOUD (FORM OF ALTO-CUMULUS).

(A. J. Henry, photo.)



2. ALTO-STRATUS AND ADVECTION FOG, SEEN FROM MOUNT WILSON, CALIF.

(F. Ellerman, photo.)

1. CUMULUS AND STRATO-CUMULUS, NEAR GAP MILLS, W. VA.

(L. W. Humphreys, photo.)

2. STRATO-CUMULUS, MONTEREY BAY, CALIF.

1. NIMBUS ABOVE, FOG BELOW; SEEN FROM MOUNT WILSON, CALIF.
(F. Ellerman, photo.)

2. STRATUS ABOVE; FRACTO-STRATUS, SCUD, OR STEAM CLOUD BELOW. SAN GABRIEL RANGE, CALIF.

1. CUMULUS, FORMING FROM FOG—RARE, SEEN FROM MOUNT WILSON, CALIF.

(F. Ellerman, photo.)

2. CUMULUS, SEEN FROM MOUNT WILSON, CALIF.

(F. Ellerman, photo.)

1. CUMULUS, SEEN FROM MOUNT WILSON, CALIF.

(F. Ellerman, photo.)

2. CUMULUS, YOSEMITE NATIONAL PARK, CALIF.

1. CUMULUS, SEEN AT WILLIAMS BAY, WIS.

(E. E. Barnard, photo.)

2. CUMULUS AND FRACTO-CUMULUS, IN MONROE COUNTY, W. VA., PETERS MOUNTAIN TO LEFT.

(L. W. Humphreys, photo.)

1. CUMULUS FORMED BY CONVECTION OVER FIRE, SEEN FROM MOUNT WILSON, CALIF.

(F. Ellerman, photo.)

2. CUMULUS OVER ISLAND—KRAKATAO.

(E. E. Barnard, photo.)

1. CUMULO-NIMBUS, PENSACOLA, FLA.
(Lieut. W. F. Reed, jr., photo.)

2. CUMULO-NIMBUS, SEEN FROM MOUNT WILSON, CALIF.
(F. Ellerman, photo.)

1. MAMMATO-CUMULUS.

(L. C. Twyford, photo.)

2. LENTICULAR CLOUD (ALTO-STRATUS LENTICULARIS), SEEN FROM MOUNT WILSON, CALIF.

(F. Ellerman, photo.)

1. LENTICULAR CLOUD (CUMULUS LENTICULARIS).

(C. F. Brooks, photo.)

2. LENTICULAR CLOUD, OVER MOUNT SHASTA.

(C. A. Gilchrist, photo.)

LENTICULAR CLOUD (CUMULUS LENTICULARIS), SEEN AT FLAGSTAFF, ARIZ.

(C. O. Lampland, photo.)

1. LENTICULAR CLOUD, OVER MOUNT RAINIER (IMMEDIATELY ABOVE TOP OF MOUNTAIN).

(O. P. Anderson, photo.)

2. CREST CLOUD, LEE SIDE, SEEN FROM HONOLULU.

(A. M. Hamrick, photo.)

1. BANNER CLOUD, MOUNT ASSINIBOINE, NEAR BANFF, CANADA.

(C. D. Walcott, photo.)

2. SCARF CLOUD, OVER CUMULUS, AT MOUNT SHASTA, CALIF.

(C. A. Gilchrist, photo.)

1. SCARF CLOUD, ON TOP OF CUMULUS.

(W. A. Bentley, photo.)

2. TONITRO-CIRRUS (FALSE CIRRUS), OVER THE VALLEY OF VIRGINIA.

(A. J. Weed, photo.)

1. FUNNEL CLOUD (TORNADO CLOUD), SEEN NEAR ELMWOOD, NEBR., APRIL 6, 1919.

(W. A. Wood, photo.)

2. FUNNEL CLOUD (TORNADO CLOUD), FROM TWO EXPOSURES TAKEN CLOSE TOGETHER, UPPER ONE FIRST, SEEN NEAR ELMWOOD, NEBR., APRIL 6, 1919.

(G. B. Pickwell, photo.)

FUNNEL CLOUD (TORNADO CLOUD).

1. CREPUSCULAR RAYS, SEEN ON THE POTOMAC RIVER.

(P. E. Budlong, photo.)

2. LIGHTNING, SEEN FROM MOUNT WILSON, CALIF.

(F. Ellerman, photo.)

1. RAINBOW, PRIMARY, SECONDARY, AND SUPERNUMERARIES: SEEN AT ABERDEEN, SCOTLAND.

(G. A. Clarke, photo.)

2. CORONA, TRIPLE, AND 22° HALO.

Drawn from observation, by G A. Clarke, Aberdeen, Scotland.

SOME ASPECTS OF THE USE OF THE ANNUAL RINGS OF TREES IN CLIMATIC STUDY.[1]

By Prof. A. E. Douglass,
University of Arizona.

I. AFFILIATIONS.

Nature is a book of many pages and each page tells a fascinating story to him who learns her language. Our fertile valleys and craggy mountains recite an epic poem of geologic conflicts. The starry sky reveals gigantic suns and space and time without end. The human body tells a story of evolution, of competition and survival. The human soul by its scars tells of man's social struggle.

The forest is one of the smaller pages in nature's book, and to him who reads, it too tells a long and vivid story. It may talk industrially in terms of lumber and firewood. It may demand preservation physiographically as a region conserving water supply. It may disclose great human interests ecologically as a phase of plant succession. It may protest loudly against its fauna and parasites. It has handed down judicial decisions in disputed matters of human ownership. It speaks everywhere a botanical language, for in the trees we have some of the most wonderful and complex products of the vegetable kingdom.

The trees composing the forest rejoice and lament with its successes and failures and carry year by year something of its story in their annual rings. The study of their manner of telling the story takes us deeply into questions of the species and the individual, to the study of pests, to the effects of all kinds of injury, especially of fire so often started by lightning, to the closeness of grouping of the trees, and to the nearness and density of competing vegetation. The particular form of environment which interests us here, however, is climate with all its general and special weather conditions. Climate is a part of meteorology, and the data which we use are obtained largely from the Weather Bureau. Much

[1] Address of the president of the southwestern division of the American Association for the Advancement of Science, Tucson, Ariz., Jan. 26, 1922. Reprinted by permission from the Scientific Monthly, Vol. XV, No. 1, July, 1922.

helping knowledge needed from meteorology has not yet been garnered by that science. For example, the conditions for tree growth are markedly different on the east and west sides of a mountain or on the north and south slopes. The first involves difference of exposure to rain-bearing winds, and the second means entirely different exposure to sun and shade. The latter contrast has been studied on the Catalina Mountains by Forrest Shreve. Again, the Weather Bureau stations are largely located in cities and, therefore, we can not get data from proper places in the Sierra Nevada Mountains of California, where the Giant Sequoia lives. Considering that this Big Tree gives us the longest uninterrupted series of annual climatic effects of known date, which we have so far obtained from any source, it must be greatly regretted that we have no good modern records by which to interpret the writing in these wonderful trees, and, so far as I am aware, no attempt is yet being made to get complete records for the future.

In reviewing the environment, one must go another step. One of the early results of this study was the fact that in many different wet climates the growth of trees follows closely and sometimes fundamentally certain solar variations. That means astronomical relationship. It becomes then an interesting fact that the first two serious attempts to trace climatic effects in trees were made by astronomers. I do not know exactly what inspired Professor Kapteyn, the noted astronomer of Groningen, Holland, to study the relation of oak rings to rainfall in the Rhineland, which he did in 1880 and 1881 (without publishing), but for my own case I can be more explicit. It was a thought of the possibility of determining variations in solar activity by the effect of terrestrial weather on tree growth. This, one notes, assumed an effect of the sun on our weather and recognized trees as one of nature's great recording mechanisms.

But the possible relationship of solar activity to weather is a part of a rather specialized department of astronomical science, called astrophysics. And there is a great deal of help which one wants from that science, but which one can not yet obtain; for example, the hourly variations in the solar constant. I would like to know whether the relative rate of rotation and the relative temperatures of different solar latitudes vary in terms of the 11-year sun-spot period. These questions have to do with some of the theories proposed in attempting to explain the sun-spot periodicity. We do not know the cause of the 11-year sun-spot period. Here then is work for the astronomers.

Yet another important contact has this study developed. The rings in the beams of ancient ruins tell a story of the time of build-

ing, both as to its climate and the number of years involved and the order of building. This is anthropology. It will be mentioned on a later page.

Viewed through the present perspective, there is one way of expressing the entire work which shows more clearly its human end, a contact always worth emphasizing. If the study works out as it promises, it will give a basis of long-range weather forecasting of immense practical value for the future and of large scientific value in interpreting the climate of the past. This statement of it carries to all a real idea of the central problem.

II. YEARLY IDENTITY OF RINGS.

The one fundamental quality which makes tree rings of value in the study of climate is their yearly identity. In other words, the ring series reaches its real value when the date of every ring can be determined with certainty. This is the quality which is often taken for granted without thought and often challenged without real reason. The climatic nature of a ring is its most obvious feature. There is a gradual cessation of the activity of the tree owing to lowered temperature or diminished water supply. This causes the deposition of harder material in the cell walls, producing in the pine the dark hard autumn part of the ring. The growth practically stops altogether in winter and then starts off in the spring at a very rapid rate with soft white cells. The usual time of beginning growth in the spring at Flagstaff, Ariz. (elevation 7,000 feet), is in late May or June and is best observed by Dr. D. T. MacDougal's "Dendrograph," which magnifies the diameter of the tree trunk and shows its daily variations. This spring growth depends upon the precipitation of the preceding winter and the way it comes to the tree. Heavy rains have a large run-off and are less beneficial than snow. The snow melts in the spring and supplies its moisture gradually to the roots as it soaks into or moves through the ground. There is evidence that if the soil is porous and resting on well cracked limestone strata, the moisture passes quickly and the effect is transitory, lasting in close proportion to the amount of rain. Trees so placed are "sensitive" and give an excellent report of the amount of precipitation. Such condition is commonly found in northern Arizona over a limestone bed rock. If the bed rock is basalt or other igneous material the soil over it is apt to be clay. The rock and the clay sometimes hold water until the favorable season is past and the tree growth depends in a larger measure on other factors than the precipitation. For example, the yellow pines growing in the very dry lava beds at Flagstaff show nearly the same growth year after year. It is sometimes large, but it has little variation. Such growth is "complacent."

Yearly identity is disturbed by the presence of too many or too few rings. Surplus rings are caused by too great contrast in the seasons. The year in Arizona is divided into four seasons, two rainy and two dry. The cold rainy or snowy season is from December to March, and the warm tropical summer, with heavy local rainfall, occurs in July and August. Spring and autumn are dry, the spring being more so than the autumn. If the snowfall of winter has not been enough to carry the trees through a long dry spring, the cell walls in June become harder and the growing ring turns dark in color as in autumn. Some trees are so strongly affected that they stop growing entirely until the following spring. A ring so produced is exceptionally small. But others near by may react to the summer rains and again produce white tissue before the red autumn growth comes on. This second white-cell structure is very rarely as white as the first spring growth and is only mistaken for it in trees growing under extreme conditions, such as at the lowest and driest levels which the yellow pines are able to endure. Such is the condition at Prescott or at the 6,000–7,000-foot levels on the mountains about Tucson. A broken and scattered rainy season may give as many as three preliminary red rings before the final one of autumn. In a few rare trees growing in such extreme conditions, it becomes very difficult to tell whether a ring is formed in summer or winter (that is, in late spring or late autumn). Doubling has become a habit with that particular tree—a bad habit—and the tree or large parts of it can not be used for the study of climate.

But let us keep this clearly in mind: This superfluous ring formation is the exception. Out of 67 trees collected near Prescott, only 4 or 5 were discarded for this reason. Out of perhaps 200 near Flagstaff, none has been discarded for this reason. Nearly 100 yellow pines and spruces from northwestern New Mexico have produced no single case of this difficulty. The sequoias from California, the Douglas firs from Oregon, the hemlocks from Vermont, and the Scotch pines from north Europe give no sign of it. On the other hand, 10 out of 16 yellow pines from the Santa Rita Mountains south of Tucson have had to be discarded and the junipers of northern Arizona have so many suspicious rings that it is almost impossible to work with them at all. Fossil cypresses also give much trouble.

The other difficulty connected with yearly identity is the omission of rings. Missing rings occur in many trees without lessening the value of the tree unless there are extensive intervals over which the absence produces uncertainty. A missing ring here and there can be located with perfect exactness and causes no uncertainty of dating. In fact, so many missing rings have been found after care-

ful search that they often increase the feeling of certainty in the dating of rings.

Missing rings occur when autumn rings merge together in the absence of any spring growth. This rarely, if ever, occurs about the entire circumference of the tree. There are a few cases in which, if the expression may be excused, I have traced a missing ring entirely around a tree without finding it. I have observed many cases in which the missing ring has been evident in less than 10 per cent of the circumference. Some are absent in only a small part of their circuit. I have observed change in this respect at different heights in the tree, but have not followed that line of study further. It is beautifully shown in the longitudinally bisected tree.

One sees from this discussion what the probable errors may be in mere counting of rings. In the first work on the yellow pines the dating was done by simple counting. Accurate dating in the same trees (19 of them) later on showed that the average error in counting through the last 200 years was 4 per cent, due practically always to missing rings. A comparison in seven sequoias between very careful counting and accurate dating in 2,000 years shows an average counting error of 35 years, which is only 1.7 per cent.

Full confidence in yearly identity really comes from another source. The finding of similar distribution of large and small rings in practically all individuals of widely scattered groups of trees over great periods of time has been evidence enough to make us sure. This comparison process between groups of rings in different trees has received the rather clumsy name of "cross-identification." Cross-identification was first successful in the 67 Prescott trees, then was carried across 70 miles to the big Flagstaff groups. Later it was found to extend 225 miles further to southwestern Colorado with extreme accuracy, 90 per cent perhaps. This is over periods of more than 250 years. Catalina pines from near Tucson have a 50 per cent likeness to Flagstaff pines. There are many points of similarity in the last 200 years and many differences. Santa Rita pines are less like the Flagstaff pines than are the Catalinas. In comparison with the California sequoias, differences become more common. The superficial resemblance to Arizona pines is 5 or 10 per cent only. That is, out of every 10 or 20 distinctive rings with marked individuality, one will be found alike in California and Arizona. For example, A. D. 1407, 1500, 1580, 1632, 1670, 1729, 1782, 1822, and 1864 are small in Arizona pines and California sequoias. While only a few extreme individual years thus

match, there are correspondences in climatic cycles to which attention will be called later.

Cross-identification is practically perfect amongst the sequoias stretching across 15 miles of country near General Grant National Park. Trees obtained near Springville, some 50 miles south, show 50 to 75 per cent resemblance in details to the northern group. This was far more than enough to carry exact dating between these two localities. Cross-identification in some wet climate groups was extremely accurate. A group of 12 logs floating in the river mouth at Geffle, Sweden, showed 90 to 95 per cent resemblance to each other. The range was 100 to 200 years and there were no uncertain years at all. The same was true of some 10 tree sections on the Norwegian coast and of 13 sections cut in Eberswalde in Germany. A half dozen sections cut in a lumber yard in Munich did not cross-identify with each other. A group of 5 from a lumber yard in Christiania was not very satisfactory. A very recent group of coast redwoods from Santa Cruz, Calif., proved very unsatisfactory. The vast majority, however, have been absolutely satisfactory in the matter of cross-identification. Nothing more is needed to make the one ring a year ideal perfectly sure in the work here described, but if there were it would come in such tests as frequently occur in checking the known date of cutting or boring, with a set of rings previously dated. That has been done on many occasions in Arizona and California. To give final assurance, the record in the yellow pine was compared with statements of good and bad years, and years of famine, flood, and cold, reported in Bancroft's "History of Arizona and New Mexico," and it was found that his report identified with the character of the growth in the corresponding years of the trees.

Three results may be noted before leaving this important subject. Deficient years extend their character across country with more certainty than favorable years. A deficient year makes an individual ring small compared to those beside it. Large rings, on the other hand, are more apt to come in groups and so do not have quite the same individuality. Nor are they as universal in a forest. If they occur at a certain period in one tree, the chances are about 50 per cent that the corresponding years in the neighboring trees will be similarly enlarged. If, however, a very small ring occurs in a tree, the chances are over 90 per cent that the neighboring trees will show the same year small.

Second, with many groups of trees where the resemblance between their rings is strikingly exact, a small number of individuals such as 5 will answer extremely well for a record, and even fewer will give valuable and reliable results. But the central part of a tree has larger growth and is less sensitive than the outer part. Its

character is somewhat different. To get a satisfactory representation through several centuries, therefore, it is better to combine younger trees with older ones to get a more even and constant record of climatic conditions.

The third thought is this. The spreading of a certain character over many miles of country stamps it in almost every case as climatic in origin, because climate is the common environment over large areas.

III. NUMBER AND LOCATION OF TREES.

The whole number of trees used is nearly 450 and includes cone-bearing trees from Oregon, California, Arizona, New Mexico, Colorado, Vermont, England, Norway, Sweden, Germany, and Bohemia. The total number of rings dated and measured is well over 100,000. The average ages found in these various trees are very interesting. The European groups reach for the most part about 90 years, although one tree in Norway showed 400 years of age, and 15 were found beginning as early as 1740. The Oregon group of Douglas firs goes back to about 1710, the Vermont hemlocks reach 1654, the Flagstaff yellow pines give a number of admirable records from about 1400.

The oldest trees, of course, were the great sequoias from the Sierra Nevada Mountains in California. They were found to have ages that formed natural groups, showing probably a climatic effect. There are very few under 700 years old (except the young ones which have started since the cutting of the Big Trees). A number had about that age. The majority of the trees scatter along in age from 1,200 up to about 2,200 years, at which age a large number were found. One or two were found of 2,500 years, one of 2,800, one of 3,000, one at just under 3,100, and the oldest of all just over 3,200. The determination of this age of the older sequoias in the present instance is not merely a matter of ring counting, but depends upon the intercomparison of some 55,000 rings in 35 trees. In 1919 a special trip was made to the Big Trees and samples from a dozen extra trees obtained in order to decide the case of a single ring, 1580 A. D., about which there was some doubt, and it was apparent that the ring in question stood for an extra year. This was corrected and it now seems likely that there is no mistake in dating through the entire sequence of years, but if not correct the error is certainly very small.

IV. TOPOGRAPHY.

The late Prof. W. R. Dudley, of Stanford University, in his charming essay on the "Vitality of the Sequoia" refers to the fact that the growth of the Big Trees depends in a measure on the presence of a

brook near by. This agrees with my own observations. Size is far from a final indication of age. The General Grant tree, which has no running water near it and is the largest in the park of that name, has a burnt area on one side in which the outer rings are exposed, allowing an estimate of its average rate of recent growth. From much experience with the way the sequoia growth is influenced by age, it was possible to assign 2,500 years as the approximate time it took this giant to reach its present immense diameter of close to 30 feet. But about 3 miles west near a running brook is a stump which is over 25 feet in diameter, but is only about 1,500 years old. That is the effect of contact with an unfailing source of water.

Perhaps the most general characteristic which stands out in the different groups of dry-climate trees is a close relationship of this kind between the topography and the growth produced. For that reason, I have visited the site of every dry-climate group and indeed have examined the stumps of almost every tree in my collection.

It was found that dry-climate trees which grew in basins with a large and constant water supply, and this refers especially to the sequoias, usually produced rings without much change in size from year to year. This character of ring is called "complacent." The opposite character is the " sensitive " ring where a decided variation is shown from year to year. Sensitive trees grow on the higher elevations where the water supply is not reliable and the tree must depend almost entirely on the precipitation during each year. Such trees grow near the tops of ridges or are otherwise separated from any collection of water in the ground. In case of the basin trees, one could be sure that a ring was produced every year, but owing to the lack of individuality in the rings for certain years, it was difficult to compare trees together and produce reliable data. In case of the sensitive tree growing in the uplands there was so much individuality in the rings that nearly all of the trees could be dated with perfect reliability, but in extreme cases the omission of rings in a number of trees required special study. Of course, these cases were easily settled by comparison with other trees growing in intermediate localities.

Trees growing in the dry climate of Arizona at an altitude where they have the utmost difficulty in getting water to prolong life become extraordinarily sensitive. In the same tree one finds some rings several millimeters across and others microscopic in size or even absent.

In order to express this different quality in the trees a criterion called mean sensitivity is now under investigation. It may be defined as the difference between two successive rings divided by their mean. Such quotients are averaged over each decade or other period

desired and are believed to depend in part on the relative response of the trees to climatic influences. The great sensitiveness of the yellow pines as compared with the best sequoias is evident in any brief comparison of dated specimens.

V. INSTRUMENTS.

In the course of this long attention to the rings of trees and in studying such a vast number of them, special tools to secure material and to improve and hasten the results have very naturally been adopted or developed. One goes into the field well-armed, carrying a flooring saw with its curved edge for sawing half across the tops of stumps, a chisel for making numbers, numerous paper bags for holding fragments cut from individual trees, a recording notebook, crayon, a shoulder bag, camera, and especially a kindly, strong-armed friend to help in the sawing. In the last 18 months the Swedish increment borer has been used extensively to get records from living pine trees. Hardwoods and juniper are too tough. It has previously been considered that the little slender cores, smaller than a pencil, so obtained, would hardly be worth working on. But the method of mounting them has been raised to such a degree of efficiency, and the collection of material becomes so rapid that the deficient length and the occasional worthless specimen are counterbalanced. Besides, it is often easy to supplement a group of increment cores by some other form of specimen extending back to greater age. The Mount Lemmon group, near Tucson, has eight cores giving a good record from about 1725 to the present time; a saw-cutting from a large stump in Summerhaven carries the record back 150 years earlier. It should, however, be supported by at least one more long record and this can be done by the tubular borer described next.

The tubular borer was designed especially for the dried and sometimes very hard logs in the prehistoric ruins. It works well on pine trees and junipers. It gives a core an inch in diameter, which means a far better chance of locating difficult rings than in the increment borer cores which are only one-fifth of that diameter. The borer is a 1-inch steel tube with small saw teeth on one end and a projection at the other for insertion in a common brace. A chain drill attachment is also provided to help in forcing the drill into the wood. The difficulty with this borer is the disposal of sawdust and the extraction of the core. For the former, a separate hole is bored with a common auger just below the core (if in an upright tree) and in advance of it to catch the sawdust. The core is broken off every three inches and pulled out to make more room for the sawdust. To extract the core a small steel rod is provided with

a wedge at one end and a screw at the other. One and two foot tubes are carried so that it is possible to reach the centers of most pine trees. It would not be difficult to develop an instrument much more efficient than this and it should be done. Soon a borer will be needed to pass through a 35-foot tree or to sound the depths of the great Tule trees of southern Mexico.

The tools just mentioned are technical, yet in no sense complex. A measuring instrument has just been completed whose usefulness will be extensive and whose details of construction are too complex for present description. It is for measuring the width of rings. It makes a record as fast as one can set a micrometer thread on successive rings. The record is in the form of a plot drawn in ink to scale on coordinate paper so that the values can be read off from it at once for tabulation. This form of record was desired because individual plots have long been made to help in selecting the best trees and in studying their relation to topography. The instrument as constructed magnifies 20, 40, or 100 times, as desired. It can be attached to the end of an astronomical telescope and used as a recording micrometer capable of making a hundred or more settings before reading the values. It seems possible that it will have other applications than the ones here mentioned.

Another instrument of entirely different type has been developed here since 1913. Its general principle has been published and will not be repeated, but in the last three years it has been entirely rebuilt in a more convenient form through the generosity of Mr. Clarence G. White of Redlands. This instrument is now known as the White periodograph. It could be called a cycloscope or cyclograph. Its purpose is to detect cycles or periods in any plotted curve. It differs from previous instruments performing harmonic analysis in that it is designed primarily to untangle a complex mixture of fairly pronounced periods while others determine the constants of a series of harmonic components. For example, the periodograph can be applied to a series of rainfall records to find if there are any real periods operating in a confused mixture. It is also designed to get rid of personal equation and to get results quickly. The instrument as reconstructed is far more convenient and accurate in use and has already given important results. It enables one to see characteristics in tree growth variation which are not visible to the unaided eye. It is specially arranged now to give what I have called the differential pattern or cyclogram because this pattern not only tells the periods or cycles when properly read but shows the variations and interferences of cycles and possible alternative readings. Tests on the accuracy of solutions by this instrument show that its results correspond in precision to least-square solutions.

VI. CORRELATIONS.

It is no surprise that variations in climate can be read in the growth rings of trees, for the tree ring itself is a climatic product. It is an effect of seasons. The geologists use the absence of rings in certain primitive trees as an indication that no seasons existed in certain early times. Whatever may have been the cause of that absence, we recognize that the ring is caused primarily by changes in temperature and moisture. Now if successive years were exactly alike, the rings would be all of the same size with some alteration with age and injury. But successive years are not alike and in that difference there may be some factor which appeals strongly to the tree. In northern Arizona, with its limited moisture and great freedom from pests and with no dense vegetable population, this controlling factor may reasonably be identified as the rainfall. If the trees have all the moisture they can use, as in north Europe about the Baltic Sea and other wet climates, we look for it in something else. It could be—I do not say that it is—some direct form of solar radiation. It could be some special combination of the ordinary weather elements with which we are familar. Shreve has studied this phase in the Catalinas. If the abundance of moisture is so great as actually to drown the tree, then decrease in rainfall which lowers the water table below ground will be favorable. A fact often forgotten is that more than one factor may enter into the tree rings at the same time, for example, rainfall, temperature, and length of growing season. These may be isolated in two ways. We may select a special region, as northern Arizona, where nature has standardized the conditions, leaving one of them, the rainfall, of especial importance. Or we may isolate certain relationships as in any other investigation, by using large numbers of observations, that is, many trees, and averaging them with respect to one or another characteristic. For example, I can determine the mean growth curve of the Vermont hemlocks and then compare it separately with rainfall and solar activity, and I may, and do, find a response to each. For that reason, I have felt quite justified in seeking first the correlation with moisture. A temperature correlation doubtless exists and in fact has been noted, but its less minute observance does not lessen the value of the rainfall relationship.

The first real result obtained in this study was in 1906, when it became apparent that a smoothed curve of tree growth in northern Arizona matched a smoothed curve of precipitation in southern California since 1860. That degree of correlation is now extensively used in the Forest Service. This was followed almost at once by noting a strikingly close agreement between the size of individual

rings and the rainfall for the corresponding years since 1898, when the Flagstaff weather station was established. The more detailed comparison between rainfall and ring growth was made with Prescott trees in 1911. Some 67 trees in five groups within 10 miles of Prescott were compared with the rainfall at Whipple Barracks and Prescott which had been kept on record since 1867. The result was very interesting. For most years the tree variations agree almost exactly with the rainfall, but here and there is a year or two of disagreement. The cause of these variable years will sometime be an interesting matter of study. Taken altogether the accuracy of the tree as a rain gauge was 70 per cent. But a little allowance for conservation of moisture raised the accuracy to 85 per cent, which is remarkably good. The actual character of this conservation is not evident. At first thought it might be persistence of moisture in the ground, but the character of the mathematical formula which evaluated it allowed a different interpretation, namely, that in a series of poor years the vital activity of the tree is lessened. During the dry period, from about 1870 to 1905 or so, the trees responded each year to the fluctuations in rainfall but with less and less spirit. This lessening activity took place at a certain rate which the meteorologists call the "accumulated moisture" curve. This suggested that the conservation was in the tree itself. There is much to be done in this comparison between tree growth and rainfall, but the obstacle everywhere is the lack of rainfall records near the trees and over adequate periods of time. The five Prescott groups showed that in a mountainous country nearness was very important. But the nearest records to the sequoias are 65 miles away and at 5,000 feet lower elevation. The best comparison records for the Oregon Douglas spruce are 25 miles away. It is so nearly everywhere. The real tests must be made with records near by.

In 1912, while attempting to test this relationship of tree growth to rainfall in north Europe, I found that the Scotch pines south of the Baltic Sea showed a very strong and beautiful rhythm, matching exactly the sun-spot cycle as far back as the trees extended, which was close to a century. The same rhythm was evident in the trees of Sweden, and perhaps more conspicuous in spruce than pine. Near Christiania the pines were too variable to show it, but it reappeared on the outer Norwegian coast. To the south near the Alps it disappeared, and in the south of England it was uncertain but probably there. In this country it shows prominently in Vermont and Oregon, but the two American maxima come one to three years in advance of the sun-spot maxima. There is evidently an important astronomical relationship whose meaning is not yet clear.

It is to be noted that it appears in regions whose trees have an abundance of moisture, and it thus appears to be a wet-climate phenomenon.

But the correlations do not stop at rain and sun-spot periodicity. The pines of northern Arizona, which are so sensitive to rainfall, show a strong half sun-spot period. And on testing it one finds that the rainfall does the same and that these variations are almost certainly related to corresponding temperature variations and to the solar period. Thus, the Arizona trees are related to the weather, and the weather is related in a degree, at least, to the sun. Thus, we find evidence in forest trees that the 11-year sun-spot period prevails in widely different localities and in many places constitutes the major variation. This introduces us to the study of periodic effects in general.

VII. CYCLES.

Considering first that cycles, as we have just shown, are revealed in tree growth, second, that the trees give us accurate historic records for hundreds and even thousands of years, and third, that simple cycles or even some more complex function could give a basis for long range weather forecasting, we recognize the vital importance of this elemental part of the story told by the trees. It was exactly for this purpose that the periodograph was designed and constructed and some 10-score curves have been cut out for analysis, after minute preparation of the very best yearly values. In fact the major time for two years has been given to this preparation of material. It is hardly done yet, but it is far enough along to anticipate its careful study in the near future. Our present view may be profoundly modified, but it is safe to say that the sun-spot cycle and its double and triple value are very general. The double value, about 22 years, has persisted in Arizona for 500 years, and in some north European localities for the century and a half covered by our tree groups. The triple period, essentially Brückner's cycle, has operated in Arizona for the last 200 years and in Norway for nearly 400 at least. A 100-year cycle is very prominent throughout the 3,000 years of sequoia record and also in the 500 years of yellow pine. A hypothesis covering all these sun-spot multiples will be tested out in the coming months. Should a real explanation be found a step will have been made toward long-range prediction and an understanding of the relationship of the weather and the sun. Other periods, however, than the multiples of the sun-spot period do occur, and general analysis shows that different centuries are characterized by different combinations of climatic cycles. This suggests to us a great and interesting problem. If we

can establish the way in which different regions act and react at the same time, then it may become possible to determine the age of an ancient buried tree by finding the combination of short cycles its rings display and then determining when this combination or its regional equivalent existed in our historic measuring tape, the great sequoia.

VIII. PREHISTORIC RECORDS IN TREES.

A new method of investigating the relative age of prehistoric ruins has been developed in connection with this study of climate by the growth of trees, and is being applied to the remarkable ruins at Aztec, in northwestern New Mexico, with its 450 rooms, now in process of excavation by the American Museum of New York City. The ceilings were built of tree trunks placed across the width of the rooms. Smaller poles were laid across these beams and covered with some kind of brush and a thick layer of earth. The beams used in this ceiling construction are almost entirely of yellow pine or spruce and for the most part are in good condition. Many of the rooms have been hermetically sealed for centuries. The beams which have been buried in dust or adobe or in sealed rooms are well preserved. Only those which have been exposed to the air are decayed.

In 1915, Dr. Clark Wissler of the American Museum offered sections of such beams for special study of the rings, knowing the writer's work upon climatic effects in the rings of trees. This offer was gladly accepted, and some preliminary sections were sent at once from the Rio Grande region. These first sections showed that the pines and spruces were far better than cedars for determining climatic characteristics.

The next lot of sections came from Aztec and was cut from loose beams which had been cleared out of the rubbish heaps. Six of these sections cross-identified so perfectly that it was evident that they had been living trees at the same time. This success led to my visit to Aztec in 1919 and a close examination of this wonderful ruin. It was at once apparent that an instrument was necessary for boring into the beams to procure a complete sample of the rings from center to outside, and that the process must avoid injuring the beams in any way. Such an instrument was developed in the tubular borer as already described. This tool was sent to Mr. Morris and during 1920 he bored into all the beams at Aztec then available and sent me the cores.

These cores, together with other sections of beams too frail for boring, finally represented 37 different beams in some 20 different rooms scattered along the larger north part of the ruin. Practically all of these show similar rings near the outside, and by

counting to the last growth ring of each it was easy to tell the relative dates at which the various timbers were cut.

In order to help in describing given rings in these various sections, a purely imaginary date was assumed for a certain rather large ring which appeared in all the timbers. This was called R. D. (relative date) 500, and all other rings earlier or later are designated by this system of relative dates. Many interesting results were evident as soon as the various relative dates were compared. In the first place, instead of requiring many hundreds of years in construction as any one would suppose in looking at the ruin, the larger part of it was evidently erected in the course of 10 years, for the dates of cutting the timbers found in the large north side include only eight or nine years. The earliest timbers cut were in the northeast part of the structure. The later timbers are at the northwest, and it is evident that the sequence of building was from the easterly side to the westerly side, ending up with the westerly end and extending toward the south.

In one place beams from three stories, one over the other, were obtained. The top and bottom ceiling timbers were cut one year later than those of the middle ceiling, showing that in vertical construction the three floors were erected in immediate succession. A floor pole from Pueblo Bonito was cut one year later than the latest beam obtained from that ruin.

An even more interesting fact was soon after disclosed. A study of the art and industries of neighboring ruins had satisfied Mr. Nelson and Mr. Morris of the American Museum that some of the ruins in Chaco Canyon, some 50 miles to the south, were not far different in age from those at Aztec. The only beams immediately available from the Chaco Canyon ruins had been collected in the Pueblo Bonito ruin 25 years before by the Hyde expedition. Accordingly sections were cut from seven beams which this expedition had brought back to New York City. One of these sections was a cedar and has not yet been interpreted, but the others were immediately identified in age both among themselves and with reference to the Aztec timbers. It was found that these Pueblo Bonito beams were cut within a few years of each other at a time preceding the cutting of the timbers at Aztec by 40 to 45 years. Many of the timbers of each ruin were living trees together for more than 100 years and some even for 200 years, and there seems no possible doubt of the relative age here determined. This result showing that a Chaco Canyon ruin was built nearly a half century before Aztec is the first actual determination of such a difference in exact years. A single beam from Peñasco, some 4 miles down the Chaco Canyon from Pueblo Bonito showed that its building was intermediate between Pueblo Bonito and Aztec.

Another association of growth rings with prehistoric deposits has rapidly developed in the last two years. In 1904 the writer discovered an Indian burial at a depth of 8 feet in a cultivated field near Flagstaff, Ariz. A skeleton and two nests of pottery were revealed by a deep cut which a stream of water had made through the land. Near the burial was an ancient pine stump standing in place 16 feet underground. The tree was later discovered by a neighbor and became part of a bridge support. The Indian remains were given away except a red bowl of simple pattern and a good piece of black-and-white ware which is now in the Arizona State Museum. In 1920 the search for these buried trees was resumed and more than a half dozen in excellent preservation were found at depths from 4 to 12 feet. Mr. L. F. Brady of the Evans School gave most important help in getting out sections of these. In the summer of 1921 he again resumed the search and found several more buried trees and especially determined several levels at which pottery and other Indian remains are plentiful. These buried trees have been preserved by their pitch and show here and there quantities of beautiful little white needle-shaped crystals, which Doctor Guild has discovered to be a new mineral and to which he has given the name "Flagstaffite."

Several conclusions are already evident in the study of these buried trees. In the first place they supply much desired material from which some data regarding past climates may be obtained. The trees buried most deeply have very large rings and a certain kind of slow surging in ring size. Both of these features are characteristic of wet climates. The stumps at higher levels show characters common in dry climates; that is, general small rings and a certain snappy irregularity with frequent surprises as to size. This variation with depth gives a strong intimation of climatic change. The cycles dominant at these different levels also may be read from these sections and are likely to prove of great value.

In the second place this material will help in determining the age of the Indian remains and perhaps even of the valley filling in which these objects were located. There are several ways of getting at this which will take time in working out but there is one inference immediately evident. One log was buried about 2 feet, yet its rings do not tally with the 500 years of well determined rings of modern trees in that neighborhood. Allowing about a century for the sapwood lost from the buried tree and a half century more necessary to detect cross-identity, we have an approximate minimum of 350 years from that 2 feet of depth. The age of Indian relics at 9 and even 4 feet must be very considerable. It is interesting to add that

this log cross-identified perfectly with another found at about the same depth a hundred yards away.

These then are the first results of the application of the general study of tree rings to archeological work and suggest further possibilities. Not only does it seem probable that this beginning of relative chronology of the wonderful ruins of the Southwest will be extended to include other ruins in this region, but this study of the prehistoric writing in trees will help in the clearer understanding of the climatic conditions which existed in those earlier times when the largest bona fide residences in the world were being built.

IX. CONCLUSION.

The economic value of this study of tree rings and climate is to be found in the possibility of long-range weather forecasting. In noneconomic terms, we are trying to get the interrelationships between certain solar and terrestrial activities by the aid of historical writing in the trees. The work is not done; a wide door is open to the future. Hence it is impossible to make an artistic conclusion. There is no real conclusion yet. Some definite results have been reached and they encourage us to hope for larger returns in the future. Through this open door we can see attractive objectives looming above us and we note the outlines of some of the hills to be surmounted. To climb these metaphorical hills we need groups of trees from all parts of this country, from numerous specially selected spots and areas, from distant lands; we need ancient tree records from Pueblo ruins and modern Hopi buildings, from mummy case and viking ship, from peat bog and brown-coal mine, from asphalt bed and lava burial and from all ancient geologic trees in wood and stone and coal. We need measuring instruments, workers, museum room for filing and displaying specimens. And we need great quantities of climatic data obtained with special reference to tree comparison. With all this and with a spirit behind it, we shall quickly read the story that is in the forest and which is already coming to us through the alphabet of living trees.

THE AGE OF THE EARTH.[1]

By T. C. Chamberlin and Others.

THE AGE OF THE EARTH FROM THE GEOLOGICAL VIEWPOINT.

By T. C. Chamberlin,
University of Chicago.

GENERAL INTRODUCTION.

In pioneer days, when the sciences were struggling for a place in the sun, it fell to geology to pull up and set back the stakes that man had stuck to mark the beginning of the earth. This seemed to many a moving of sacred landmarks; to others it seemed a wanton use of the secrets of the cemetery of nature's dead. A bitter war arose; racial bias disputing the rock beds, tradition and sentiment fighting mud layers and fossil imprints. The struggle that followed was long. The throwing of rocks and rock-ribbed arguments grew to be an art that might well have drawn forth the envy of an Ajax. But the substantial slowly gained on the sentimental. The brutal cogency of a slab of fossils could be hated and fought, but could not be gainsaid. And as the tide turned the geologist began to play crusader; he mounted his war horse and went forth to convert the world—including, withal, some of his scientific colleagues.

After a time, however, the battle shifted to another field. Darwin and Wallace drew off a following and taught them to use the subtler weapons of "the struggle for existence" and "natural selection." However, they still plied the old geologic weapons, for they, too, had reason to point to bed on bed; they had need of even more time than the geologists. So they took the lead and the team became a tandem, biology prancing in front, geology trotting on in the thills.

But the spirit and abandon of this team soon awakened a new antagonist. Kelvin took the field in the name of physics, astronomy, and mathematics, and sought to set metes and bounds to the backward extension of terrestrial time. He told the tandem, with much show of premises and figures, that the feed on hand positively would not let them go as far as they proposed. The tandem was reined in

[1] Reprinted by permission from Proceedings of the American Philosophical Society, Vol. LXI, Dec. 26, 1922.

and marked time, losing not a little of the free natural pace it should have retained.

But in time this great antagonist was neatly flanked from an unexpected quarter. Certain physicists and chemists discovered that they had a decaying atom on hand. They keenly watched its rate of decay and soon came to see that if atoms take as long to grow as some of them take to die off, there should have been time enough for this little ball of atoms to get together—and plenty of energy as well.

So, too, astronomers began to see that the making of globular clusters and stellar galaxies required time. If 60,000 suns have time to come together and work themselves into a steady state while yet they are suns, the getting together of our little earth may be merely a negligible matter after all. And so a new order of things has arisen. The tandem is a vexed tandem no longer. We now have a fine four-horse team: Astronomy and physics at the front, leading off at a great pace; biology on the pole, steadying the team; and geology plodding on as the old original wheel horse.

THE GEOLOGIC PROBLEM.

Now, I must hasten to warn you not to expect much of the old wheel horse. He has grown stiff in his paces, and his paces are not what they should have been. Kelvin checked him too high. A reasonable check should have given him good form and some sense of restraint, but checked too high, he took to short mincing steps. As a result he is in poor shape to swing into the great pace of the new leaders. It is too much to expect him to recover his natural step at once, but he will in time. For the present, he will need a touch of the whip now and then to make him keep pace. Let this be gentle and considerate, because of his age and his past service, but let it be persuasive.

REPRESENTATIVE GEOLOGIC TIME ESTIMATES.

It is a simple matter, theoretically, to use the rate at which sediments are being laid down, or solutions gathered into the ocean, as a divisor to find the time required to lay down the whole column of sediments or the whole accumulation of the salts in the sea. Practically there are serious difficulties. In the first dozen years of this century four notable estimates were made in this way by able geologists—two Americans, Clarke [1] and Becker; [2] two British, Joly [3] and

[1] F. W. Clarke, "A preliminary study of chemical denudation," Smithsonian Misc. Coll., lvi, no. 5 (1910); "The data of geochemistry."

[2] George F. Becker, "The age of the earth," Smithsonian Misc. Coll., lvi, no. 6 (1910).

[3] J. Joly, "An estimate of the geological age of the earth," Trans. Roy. Soc. Dublin, VII (1899), pp. 23–66; "The age of the earth," Phil. Mag., 6th ser., Vol. XXII (1911), pp. 359–380.

Sollas.[4] These estimates form an admirable point of departure for this discussion. They represent the mode of geologic interpretation that has been most current until recently; they typify opinions widely held by the conservative school of geologists; they stand out in contrast to the views of the new school.[5] The mean of the four estimates, on the basis of the sediments, was 90,000,000 years, roundly; on the basis of the ocean, 95,000,000 years. The highest individual estimate was 150,000,000 years; the lowest 70,000,000 years. I shall not deal with the individual estimates, but merely with their mean value, and with that only as representative.

My discussion can not be specific and concrete without some reference to views in other fields. My colleagues in this symposium will give you the last word from their viewpoints, and if I could follow them I would gladly take their estimates as specifically representative in their several lines. In lieu of this, I can only use such general views as are current. It has long been known to be the view of many biologists that the evolution of life required much more than 100,000,000 years. It is also well known that most estimates based on radio-activity greatly exceed this. Astronomical opinion has recently been trending toward the view that long periods are necessary for certain typical phases of celestial evolution. Perhaps I may overstep my proper limits far enough to say that I have recently tried to form some notion of the time required for the gathering of planetesimals from what seemed a probable distribution into the collecting planetary nuclei, and found a period of the order of two or three billion years the most probable.[6] These current views in the collateral fields warrant me in assuming that there is a wide discrepancy between the geological estimates just cited and the present estimates in the related fields. In view of this I can perhaps serve you best by inquiring whether the recent additions to geologic evidence and the newer modes of interpretation mitigate this discrepancy in any appreciable measure. Let us consider first what the newer evidence relative to the sediments has to say, and turn later to the solutions.

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[4] W. J. Sollas, "Presidential address," Quart. Jour. Geol. Soc., vol. 65 (May, 1909), Proc. Geol. Soc. of London., sess., 1908–9, pp. l–cxxii.

[5] It is not practicable to summarize the time estimates of the newer school consistently with the division of labor adopted in this symposium since they are composite, embracing organic, astronomic, and radioactive factors, with some emphasis on the last. The following papers of this class may be taken as representative: J. Joly, "Radioactivity and geology," Van Nostrand, New York (1909), pp. 233–251; Arthur Holmes, "The age of the earth," Harper Bros., London and New York (1913), pp. 1–196; J. Barrell, "Rhythm and the measurement of geological time," Bull. Geol. Soc. Am., vol. 28 (1917), pp. 745–904; T. C. Chamberlin, "Diastrophism and the formative processes," XIII, "The time over which the ingathering of planetesimals was spread," Jour. Geol., Vol. XXVIII (1920), pp. 675–681.

[6] Diatrophism and the formative processes, XIII, The time over which the ingathering of the planetesimals was spread, T. C. Chamberlin, Jour. Geol., Vol. XXVIII (1920), pp. 675–681.

THE TESTIMONY OF THE SEDIMENTS.

In considering possible modifications of the foregoing estimates five questions arise: (1) How far do recent investigations tend to lengthen or to shorten the older estimates? (2) To what extent has human action made the present rate of wash and deposit faster than the mean pre-human rate? (3) How far does the present state of elevation make the present rate faster or slower than the mean rate of the past? (4) How does the present area of erosion compare with the mean area? And, finally, (5) does the lower end of the geologic column give us the point from which the accumulation of the sediments began? I can try to answer these questions only very briefly and inadequately.

1. *The effect of intensive studies on earlier time estimates.*— A strictly accurate chronology reaching back from the present for several thousands of years is now being worked out by De Geer.[7] He has succeeded in identifying the yearly deposits of glacial waters and in correlating them with annual moraines. In addition to this he has been able to match sections at distant points by comparing the succession of peculiarities in the annual "varve" layers. While this is a quite special method and has only limited application, it is important to general time estimates, because it gives a means of checking up other criteria that indicate glacial time, and these help check up certain nonglacial criteria. As is well known, the duration of the recent Ice Age was for a time a sharply battled question, and the old views pitted against the new views came to be well defined. Though not yet ready for precise announcement, it is already foreshadowed that the De Geer method of measurement, when it shall have fully covered the retreatal stage of the last glacial epoch, will show that stage to be about three times as long as it was made by the most representative of the old estimates. The main differences of opinion as to the duration of the glacial period, however, grew out of the evidence that instead of one simple short epoch there were several epochs of glaciation separated by rather long interglacial intervals. Now, by using the De Geer method to correct the criteria on which time estimates of these glacial and interglacial epochs have been based, a glacial period at least twenty times as long as that assigned by the old estimate seems to be foreshadowed. Very likely this degree of extension of an old-time estimate by a new one is exceptional; at any rate, the glacial formations are exceptional deposits and make up only a small part of the geologic column.

[7] Gerald De Geer, "A geochronology of the last 12,000 years," Proc. Int. Congr., Stockholm, 1910, p. 241; "Kontinentale Niveauveränderungen in Norden Europas," ibid., p. 849; Spitzbergen, ibid., p. 1205; "Phenomenes Quaternaires de Stockholm," ibid., p. 1290; "Quaternary phenomena in the southern part of Sweden," ibid., p. 1339.

In considering the standard water-lain sediments of the column, it is to be understood that only rapid surveys or mere reconnaissances have as yet been made of the larger part of the earth, and that inevitably inconspicuous breaks in the continuity of the deposits have been overlooked. As a result recent critical studies have revealed in some cases surprising numbers of gaps in the continuity of deposition. For example, Dr. Stuart Weller, in a study of what was formerly regarded as a continuous section of the Mississippian, has found no less than 12 breaks in continuity. The time value of these, in his judgment, is two or three times as great as that of the visible beds themselves.[8] The time values of such intervals are best judged by comparing the faunas below them with those above, but this falls within the province of my paleontological colleague, and I therefore leave this source of correction in his hands, merely expressing the conviction that these breaks in the continuity of the sediments are quite sure, when finally and fully adjudicated, to extend greatly the old estimates of the time occupied in sedimentation.

2. *Human acceleration of the rate of deposition.*—To pioneers who watched the effects of floods, freshets, and ordinary wash on the native surface of our prairies and forests in their virgin state, and who are able now to compare this with the present wash of the same surfaces under cultivation, there is no need to argue that human intervention has greatly hastened denudation and deposition. In the native state the surface was protected by thick mats of grass, leaves, and other vegetable débris; while the soil was bound together by dense entanglements of roots. The waters then ran almost clear where now they run mud.[9] Added to this are the quickened deflation of winds, the wear of roadways, the effects of quarrying and other excavation, as well as the actual carting away of clays, sands, gravels, quarry stone, foodstuffs, timber, and other material. While it is not easy to fix on a definite measure of these effects, the needed correction seems certainly to be large.

3. *Correction for the present elevation of the surface.*—It is held by leading American geologists that the general elevatory movements of the continents have alternated with periods of relative stability during which the processes of base leveling and sea transgression have

[8] Personal communication.

[9] A fuller statement of this with citations of data from Dole and Stabler and from F. W. Clarke is given in "Diatrophism and the formative processes, VIII, the quantitative element in continental growth," T. C. Chamberlin, Jour. Geol., Vol. XXII (1913), pp. 522–528.

cut down the continents and developed peneplains.[10] The periods occupied in the process of lowering the surface by denudation are held with good reason to be greater than those occupied in its elevation by deformative action. It is needless to say that elevation increases the velocity of the run-off, and that this velocity greatly increases the transporting power. [11] It is generally agreed that the present altitude of the continents is greater than their mean elevation during geologic history. Geologists recognize at least two stages in which the continents were exceptionally high and broad: That which attended the transition from the Paleozic to the Mesozoic Era, and that which attended the transition of the Tertiary to the present epoch. The existing stage thus falls in one of the most notable stages when continental elevation and breadth were greatest, though perhaps not at its climax. Geikie estimates the present mean elevation of the land at 2,441 feet.[12] The mean elevation of the great peneplains is a matter of judgment rather than of knowledge, but no one would probably put the elevation at much more than a third of this. Probably a third is too high. The mean elevation for all the ages, high and low, quite surely falls somewhere between 2,400 and 800 feet, and probably nearer the 800 than the 2,400. There can be little doubt, then, that the present rate of denudation and deposition is much above the mean rate.

There are incidental conditions attending high relief which add appreciably to the immediate effects of the steep declivities to which it gives rise. Relief of the surface increases the vertical air currents, and these favor precipitation; they also tend to concentrate the precipitation and give it enhanced effect. High relief often induces sharp showers and distinctly rapid run-off. The smooth surfaces of the stages of lower elevation, on the other hand, favor a more even distribution of rain, a larger absorption into the soil, and a slower run-off of the remainder. So, too, accidented surfaces are likely to be ineffectively protected by vegetation, for lack of soil, or of adequate moisture. These and other incidental influences add appre-

[10] The following group of papers emphasizes the rhythmical nature of elevation and stability and of the action of the atmosphere and hydrosphere upon the periodic deformations of the earth body and thus form the basis for the arguments in this and the next section: "A group of hypotheses bearing on climatic changes," T. C. Chamberlin, Jour. Geol., Vol. V (1897), pp. 681–683; "The ultimate basis for time divisions and the classification of geologic history," ibid., Vol. VI (1898), pp. 449–463: "A systematic source of provincial faunas," ibid., Vol. VI (1898), pp. 597–609; "The influence of great epochs of limestone formation upon the constitution of the atmosphere," ibid., Vol. VI (1898), pp. 609–622; and specifically as applied to the question of age: "Rhythm and the measurement of time," J. Barrell, Bull. Geol. Soc. Am., Vol. 28 (1917), pp. 745–904. The argument used in the present paper will be found stated as a quotation from Chamberlin in Holmes's "The age of the earth," cited above (1913), pp. 79–81. See also T. C. Chamberlin, "Diastrophism as the ultimate basis of correlation," in "Outlines of geologic history," compiled by B. Willis and R. D. Salisbury (1910), The University of Chicago Press, pp. 298–306.

[11] See the special investigation of G. K. Gilbert, "The transportation of débris by running water," Prof. Paper, 86, U. S. Geol. Surv. (1914).

[12] "Textbook of geology," 4th ed., Vol. I (1903), p. 49.

ciably to the total effect. It seems clear, therefore, that a large correction is to be made to the present rate of denudation because of the relatively high elevation of the continents.

4. *Correction for area.*—This is to a large degree, but not wholly, an effect of the elevation of the continents, but none the less it deserves separate recognition. When elevation increases the land area, base leveling and sea transgression at once set in and combine their forces to reduce the exposed area. The result is very large variations in the areas of the ancient lands. The estimates of Schuchert and others for North America show variations that range from the full surface of the continental platform down to half that surface. As a rule, of course, the lesser surfaces were also low surfaces, and the two influences were cumulative. At stages of low elevation and slack drainage deep soils were likely to accumulate, and these favored thick vegetation, which helped to hold the soils. Thus in several ways small area and low elevation united their influence in a cumulative effect which could not have been other than large.

Partial summary.—Summarizing at this point, it appears that four important corrections quite certainly must be applied to the present rate of geologic action to reduce it to a mean rate for the whole of geologic time. These corrections are cumulative. There seems to be no way at present to evaluate them rigorously or perhaps even very closely. The weighing of their value is greatly affected by the individual judgment and that, in turn, by individual experiences and opportunities of observation. Speaking for myself alone, it does not seem to be overstraining the importance of these corrections to suppose that their cumulative value will be found great enough to bring the old-time estimates up to figures of about the same order as those of the current radioactive estimates.

5. *The lower end of the geologic column.*—Below the base of the Paleozoic series the geologic terranes are much obscured by diastrophism and metamorphism. It remains to inquire what is the testimony of this obscured portion as to the horizon at which the sediments began to be deposited, for that is essential to measuring the whole period of deposition. It was once thought that the Cambrian beds lay close upon "the original crust," and that they either represented the real beginning of the sedimentary series or else an early stage close to the beginning. But as field work progressed it was found that first one and then another thick series of sediments lay below the Cambrian. It was further found that there were marked unconformities between these great terranes, and that these were of such a nature as to imply long intervals of time unrepresented by deposits; that is, times when the deposition took place elsewhere. The number of such strongly unconformable terranes has been notably increasing as investigation proceeds. The correlation

of these is not yet complete—or even wholly satisfactory so far as it has gone—but the leading workers in this field recognize six, eight, or more great stages. This pre-Cambrian factor is thus certainly great, but just how great is yet undetermined.

The mere extension of the sediments downward in this large degree is not, however, the most significant feature of this recent work. Great granitic series form a prominent feature of these lower terranes. These were formerly taken to be parts of "the original crust." They have been found, however, to consist of remarkable *intrusions* into earlier series made up of sediments, volcanic débris, and surface lava flows. The granites are not evidence of "the original crust of the molten globe." Nor does there seem to be any other trustworthy evidence of "an original crust." Thus observational evidence does not give the depth at which the bottom of the column of sediments is to be found, and theory is perhaps as favorable to a depth of a thousand or two thousand miles as any shallower depth. A reliable starting point for reckoning the total thickness of the sediments is not available.

THE TESTIMONY OF THE SOLUTIONS.[13]

In the effort to find the earth's age by means of sediments advantage may be taken of the fact that each deposit makes its own individual contribution. It is thus possible to sum up as many of these separate contributions as can be measured satisfactorily and rest the case there, leaving what remains of the earth's age to be found out later or to be guessed at or to be ignored. But when the inquiry turns to the solutions it must face the fact that the contributions of each stage have been mingled with those of all other stages and the record to be measured is thus an indivisible unit. If the ocean, considered as such record, can be used to measure age at all, it is the total age of the ocean. This total age of the ocean can not be expected to tally with the age found from an unknown fraction of sediments.

The basis of estimating the age of the ocean.—The interpretation of the time occupied in the concentration of solutions in the ocean hangs on the assumptions made relative to its origin and to the entire history of the earth's waters on land and sea alike. This includes the volume of the waters at the start and all along; it includes the metamorphic solutions from within the earth as well as

[13] Only a brief general statement could be made at the Symposium for lack of time. Adequate citation of evidence or of authority or elaboration of critical points was impracticable. The printed text gives somewhat more liberty and I have taken advantage of it to a limited extent and have recast this part of the text to accommodate it to this. I am greatly indebted to Dr. T. Wayland Vaughan, United States geologist in charge of investigations on sediments, for aid in securing documents and personal statements from the departments of our general Government and from its officials engaged in investigations bearing on the question in hand.

those that arise from surface action. Account must also be taken of such reversals of action as take material out of solution and return it to the solid state. All these must be considered, for they are all necessarily involved in the question of the age of the ocean. Some basal assumptions are unavoidable, and if we must deal with them it is best to be frank and explicit about them. The necessary assumptions as to the early stages of the ocean are more or less speculative, but if we are to discuss the question of age at all, there is no occasion to be squeamish about that. It does not make the assumptions any less "speculative" to gloss over or shy at the fact that they are speculative or at least have speculative factors. Assumptions are least dangerous when explicitly recognized. They are even likely to be least speculative when the grounds on which they rest are carefully sifted, logically weighed, and made to throw such light as they may on the question in hand. We have no call to discuss the age of the ocean at all unless we are ready to be frank about the other end of its history. The crux of the issue lies there. We are all agreed about the age of this end.

The two types of assumptions in actual use and their radical differences.[14]—Only two general types of assumptions require recog-

[14] The four estimates of the age of the ocean which were cited earlier and which give an average age of 95,000,000 years, with a range from 70,000,000 to 150,000,000 years, seem clearly to have been made on the basis of the inherited view of the origin of the earth. This assumes that all the material of the present hydrosphere, together with such substances of the present earth body as would be volatile at the temperature of molten rock, were held in the atmosphere which surrounded the supposed molten earth. The oceanic history is assumed to have begun when the waters from this primitive ocean-bearing atmosphere condensed upon the crust that had formed over the molten earth. The great influence which this view has had on geologic thought and the wide extent to which interpretations derived from it enter into various geologic concepts *not recognized as its offspring,* are chiefly due to the explicit teachings of the old masters who had clear cosmological conceptions and the courage of their convictions. Foremost of these among Americans was Dana, and as I once believed and taught this view but have become an apostate from it and the protagonist of another view, I trust that in following Dana's statement in the fourth edition of his Manual of Geology as a standard exposition I shall not be doing any injustice to the inherited view.

On the other hand, the only accretional view that has been carried out into any measure of detail is the planetesimal hypothesis. (The most recent statement of points pertinent to this discussion may be found in a series of articles entitled "Diatrophism and the formative processes," I to XV, Jour. Geol., Vols. XXI (1913) to XXIX (1921), particularly Articles X to XV.) To clear the air of needless fog let it be noted that this is not a speculation regarding the origin of the universe, or of the stars, or even of our sun. It is merely an endeavor to explain the singular dynamic properties of the earth and its fellow planets and their strange relations to the sun. It is merely a definite endeavor to solve a very definite problem. It started from an attempt to test the tenability of the inherited view of the atmosphere just outlined. The hypothesis that the atmosphere once held as vapor all the water of the ocean and much other volatile material was framed before the nature of gases was known. The view seemed logical enough under the old notion of gases. Special reasons for testing it by the kinetic theory of gases arose out of the relations of the atmosphere to glaciation. The results of the test were very unfavorable. It seemed wholly improbable under the kinetic constitution of gases that a molten earth could hold so vast and active an atmosphere. This adverse result led to other tests of a more mechanical sort. These disclosed certain critical facts in the dynamics of the solar system which, while not altogether unknown, had not been adequately recognized as indispensable criteria in the interpretation of our planery

nition here, the one based on the view that the earth started as a molten globe, the other that it grew up slowly by the accession of solid particles. For the purposes of the present question it is not radically material how the molten globe arose, on the one hand, nor by what celestial mechanism the accretion took place, on the other, beyond the fact that the material of the ocean was supposed to be assembled as a vapor about a hot earth, in the one case, ready to begin work in full volume when cooling took place, while in the other case the waters came into action very gradually. Out of these basal differences, however, there arise some important contrasts in the modes of later action that are almost equally radical in their bearings on the evolution of the ocean, so that both the original and derivative differences need to be sharply in mind in considering the question of the earth's age.

1. On the one hand, it is assumed that the ocean was essentially uniform in volume throughout all the ages, and that the disintegration of the surface rocks, the inflow of solutions, and the content they carried were also essentially uniform. If these assumptions are correct, or if they hold true of a single leading element, as sodium, the present rate and content of inflow may be used as a divisor to ascertain the total time of inflow. This, however, is subject to the condition that there is no important reversal of action, or at least none that can not be adequately measured and discounted.

The alternative view assumes that the ocean grew to its present volume very slowly from a small beginning, that the solutions came from three sources and were variable from the start, so that the whole history was very different from the preceding. The three sources of solutions were (1) the internal metamorphic action of waters entrapped in the growing accessions, (2) surficial action by the atmosphere and hydrosphere acting on the shell of the lithosphere, and (3) accessions of water-substance from the environing sphere under control of the sun—particularly accessions through the system of exchange between the ultra-atmosphere of the sun and the ultra-atmos-

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system. In other words, the earth and its family have dynamic peculiarities that make the question of their origin a special one. *These hereditary peculiarities point the way to their interpretation.* The planetesimal hypothesis is simply the result of an attempt to follow these hereditary traits back to their parentage. It is as little as possible speculative, for it starts with mechanical properties which are rigorously determinate and which must be met by any hypothesis of genesis worthy of serious consideration. It follows these back to their probable origin in other known properties and natural actions so related to them as to be their probable sources. The method followed was only a phase of the standard practice of geologists in following the vestiges of a recorded event back to their most probable sources. If peculiar at all, it is merely in that the vestiges are dynamic. It ill becomes us to be squeamish about historical deductions from historical vestiges, for there are plenty of people who regard geology as a speculation from beginning to end and there is no present help for it.

phere of the earth.[15] The first source brought one type of solutions, the second another, and the third added water that was essentially fresh. Under this view it is obvious that until this complex of sources and variations has been worked out the present rate of accession has no claims to be regarded as a trustworthy divisor for ascertaining the total period of activity.

There are also two rather radically different methods of dealing with the geo-chemical evolution of the ocean. These are not necessarily connected with the preceding differences of view, but as a matter of fact they are closely associated with them.

The first of these—associated with the older cosmological view—takes (*a*) for its start the concept of a universal crust acted upon from without by an atmosphere and hydrosphere, (*b*) for its middle factor the streams, and (*c*) for its end products the sediments and the ocean. The matter in the sediments and in the ocean taken together are supposed to match the loss of the crust by decomposition and wear. Under this view any real failure to so match is a discrepancy to be accounted for. In the special problem in hand the sodium in the ocean, together with the sodium that remains in the sediments, should match the sodium once in the denuded rocks of the crust. So, also, the other elements of the crust should appear in due proportion in the sediments and the ocean. It is recognized in the cases of calcium, magnesium, potassium, silica, and other elements that there are reversals of action by which these elements go back into the solid state as new sediments, but it is held that sodium does not return to the solid state in the sediments in a similar chemico-physical cyclic way, to any appreciable degree. Thus the sodium now in the ocean is held to represent the accumulation of all the geologic ages, and this total accumulation divided by the rate at which the present streams are carrying sodium down to the sea is held to give the age of the ocean, barring some corrections to be noted later. The crux of the whole issue of age lies in the validity of these concepts, particularly the irreversibility of the sodium.

The other view is far less simple. It looks upon the hydrosphere, of which the ocean is the chief concentration, as only the liquid phase of a solid-liquid-gaseous cycle through which the earth substances are passing. It is held that the earth is perpetually undergoing self-metamorphism in all its parts. This metamorphism takes place in a multitude of ways, each unit doing its part, in its own place, in its own way, and at its own rate. Each unit passes through its own cycles of liquid-solid-gaseous states according as its nature, its contacts, and conditions determine. Its career is wholly dependent on its own succession of conditions, and is only affected by what other

[15] "The origin of the earth," The University of Chicago Press (1916), pp. 19–21.

units are doing under their conditions incidentally as it happens to come into working relations to them. The cycles that thus arise are so multitudinous and intricate that their correlation is a most formidable task which is scarcely yet fully appreciated; little more than a beginning has been made toward its accomplishment.

Under this view it is necessary to stress the fact that the simple solid-to-solution change from the rock to the ocean does not cover the whole evolution in the case of any substance. In most cases there are many cycles, some in parallel lines, some in succession. The content of the indurated rocks, on the one hand, and the content of the sediments and the ocean solutions on the other, are great features that have guiding value, but they are too general to cover with adequate accuracy the sub-cycles that make up the real history. The correlation of the whole is too largely conditioned by the number and speed of the constituent cycles to be successfully dealt with. It is especially affected by the reversals from the liquid to the solid state which take place during the passages from rock to soil, from soil to fresh-water solutions, or to colloids and turbid suspensions, and from these to the concentrated sea solutions in the borders of the sea. The deductions drawn from such a complication of cycles differ in very important respects from the deductions drawn from a simple matching of the content of the igneous rocks with the content of the ocean solutions and the sediments.

Now, in respect to sodium, it is, of course, recognized that it returns to the solid state in less degree than potassium, magnesium, and calcium. It is held, nevertheless, on good evidence, that the sodium does return to the solid state in minor equilibrium degree and is recounted. The reactions involved are controlled by the law of mass action and the mutual effects of the constituents on one another. The reactions are particularly affected by the degrees of concentration, which are very low in the fresh-water solutions and quite high in the sea solutions. The trend of the reactions is toward equilibrium between the constituents, not toward any exclusive or monopolistic combination. Specifically, it is held that when the state of concentration favors the sodium, it will displace either potassium, magnesium, or calcium, and that such displacements take place as a standard feature in the processes of disintegration and solution, though only in an appropriate minor degree.

Let us now turn to such determinations as are available for testing the validity of these contrasted interpretations.

Discrepancies in the matching of igneous rocks with sediments and solutions.—The differences between the content of the igneous rocks and that of the sediments and the salts of the ocean have been

put in definite form by Leith and Mead.[16] Comparing first the igneous rocks with the sediments, they find the following excesses and deficiencies: (1) a *deficiency* of 3.1 per cent in iron; (2) a *deficiency* of 26 per cent in magnesium; (3) an *excess* of 32 per cent in calcium; (4) a *deficiency* of 64 per cent in sodium; and (5) an *excess* of 2 per cent in potassium. If the corresponding constituents in the ocean are added to these severally, some of the discrepancies will be lessened, while others will be increased; the discrepancies do not disappear, though they are somewhat mitigated.

2. It is recognized on all hands that the land waters vary greatly according to the nature of the drainage area from which they are derived. In some districts they consist largely of carbonates, or of sulphates; in others of chlorides, or of silicates; while the degree of dominance varies greatly within each class. The solutions of the ocean, however, are not identical with any of these, nor with a simple mixture of them; the ocean solutions are dominantly chlorides, but constitute a combination which is quite distinctive. This implies that, instead of a theoretical mixture of the land waters, an effective chemico-physical reorganization takes place, a liquid metamorphism of the heterogeneous land waters and their content into the homogeneous sea solution and its sediments. This is in a measure recognized, but the recognition is inadequate if the change is regarded simply as a liquid metamorphism. There is a neglected solid factor in the form of silts and clays that is of critical importance. The usual comparison is really between the *clear* waters of the streams—which are mainly the outflowing *ground* waters of the land—and the sea waters. The *run-off* and its contents—the wash-waters of the land and their burden of mud—are neglected. But it is this run-off water with its mud and the colloids that go with it which carries the larger part of the acid radicals of the soil from which the basic radicals were leached. The reunion of these acids with the alkalies in the border of the ocean constitutes a critical part of the metamorphism which gives rise to the ocean solutions and sediments. We will return to this presently.

3. *The larger part of the solutions now flowing into the ocean comes from the sediments; the lesser part from the igneous rocks.*—This becomes the more suggestive when it is noted that the sediments have been worked over repeatedly in some notable part; some small part, perhaps hundreds of times; some larger part, scores of times; while some other large part perhaps has not been worked more than once, unless we count in the many times most material is handled in going from the parent rock to the ocean. That the sediments should still be able to yield saline solutions to the observed extent

[16] C. K. Leith and W. J. Mead, Metamorphic geology (1915), p. 69 et seq., particularly pp. 83–88.

raises a vital question into which it is necessary to inquire before assuming the practical nonreversibility of the sodium solutions. It is already well recognized that a part of this sustained productiveness is due to sea winds which carry salt inland from the ocean. This salt is thus counted as many times as it is carried back. An endeavor has been made to estimate and make allowance for this by taking the increase of salt solutions near the ocean as a criterion. It has also been recognized that salt solutions are entrapped in the pores of the sediments as they are laid down under the sea, and that when the beds are afterwards raised above the sea level these solutions are drained into the streams and counted again as salts from the land. The amount of duplication involved in this depends on the ability of the rocks to hold salt water mechanically in their pores, and correction has been sought by estimating their porosity and discounting for it. Sandstones usually have the highest porosity and limestones come next, while shales are relatively close-textured and impervious, but still the shales are exceptionally productive. So, also, it has been recognized that beds of rock salt occur in the stratified series, but these are held to be relatively unimportant. So still further some particles of the original rock may remain undisintegrated; so, too, fresh particles may be cut away from exposed rocks by wind blast and widely though sparsely distributed. But when the modifying effects of all these have been recognized and discounted, there still remains a serious source of double counting of sodium which we must consider presently.

4. The ratio of chlorine to sodium is a crucial matter, recognized but not sufficiently emphasized. Inspection of the drainage from regions of igneous rocks shows that *the chlorine is relatively low and the sodium relatively high* compared with the ratio of these elements in the ocean, which is about 1.8 chlorine to 1 sodium. The relative deficiency of chlorine in the drainage from the very rocks that are assumed to be the ultimate source of the salt solutions raises a fundamental issue.

5. In view of this, let us make our inspection as sweeping as possible. Let us compare the ratio of sodium to chlorine in the ocean with the ratio found in the average igneous rock of the whole "crust." The latest and most authoritative determination of the chemical composition of the igneous rocks is that of Clarke and Washington, which gives the mean sodium content as 2.83 and that of chlorine as 0.096.[17] From this it appears that the mean per cent,

[17] Frank W. Clarke and Henry S. Washington, U. S. Geol. Surv. and Geophys. Lab., Carnegie Institution of Washington, "The average composition of igneous rocks," Proc. Nat. Acad. of Sci., vol. 8, no. 3 (May, 1922), pp. 108–13. In the paper as read at the symposium I used the then latest and most authoritative figures, viz, those of H. S. Washington, "The chemistry of the earth's crust," Jour. Franklin Inst., in which the sodium was given as 2.85 and the chlorine as 0.055.

of sodium in average igneous rock is *about thirty times as great as their content of chlorine.* This is a large difference, but it does not represent the full discrepancy, for the chlorine in the ocean exceeds the sodium in about the proportion of 1.8 to 1. Taking this into account, the discrepancy rises to somewhat above *50* to *1.* This is a formidable discrepancy. How is it to be met on the assumption that the sodium in solution is not reconverted into sodium solids, but remains in perpetual solution? The dilemma is not much relieved by reckoning in the sediments and the ocean salts, for Clarke and Washington also give[18] the ratio of sodium to chlorine when the atmosphere and hydrosphere are reckoned in with the outer 10 miles of the lithosphere. The discrepancy, corrected for actual oceanic proportions, is even then nearly 20 to 1. Quite naturally volcanoes have been thought to be a source of excess of chlorine, but any contribution from the volcanoes is covered by this inclusion of the whole atmosphere and hydrosphere in the average. Besides, the later studies of volcanic gases do not sustain the earlier views that they contained a specially high content of chlorine.[19] The observed differences between the sodium and the chlorine appear to have grown mainly out of the normal processes of cyclic change when these are viewed in their largest aspects. If the sodium returns to the solid state in due (though lesser) proportion to the potassium, magnesium, calcium, and chlorine, as these constituents are found mixed in the solutes and the sediments, there is no necessary discrepancy in these great differences. The discrepancy is constructive and is imposed by the assumption that the sodium does not take its proportional part in cyclic action. Under the alternative interpretation, the amounts of the several elements present in the ocean are primarily functions of their own cyclic histories; their proportions are not predetermined solely by the composition of the igneous rocks now at the surface, but rather by the relations of their own solvent to their non-solvent natures under the conditions of their long complex history. Specifically, in the case of sodium and chlorine, the observed ratio merely means that the solution stages of sodium compared with its solid stages are much inferior to those of chlorine, just as those of potassium are much inferior to those of sodium, and so on through the list. But, however cogent this may be, definite evidence that sodium does enter freely into the cyclic processes, in due proportion to the action of its associates, however inferior the proportion may be, will naturally be demanded. Allusion has already been made to a neglected factor. Let us turn to that.

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[18] Ibid., p. 114.

[19] E. T. Allen, "Chemical aspects of vulcanism with a collection of the analyses of volcanic gases." Papers from the Geophysical Laboratory, Carnegie Institution of Washington, No. 440 (1922), pp. 1–80.

The mud cycle actuated by the surface floods.—Familiar as this is in many respects, it has perhaps received less critical geochemical study than almost any other common feature of nature with which we are directly, not to say unpleasantly, brought into contact. The agricultural chemists have naturally been preoccupied with those elements of the soils that serve as plant food, the students of hygiene and domestic science with waters suitable for drinking and culinary purposes, and the geologic chemists with the organic extracts and precipitates that form the limestones, dolomites, and siliceous beds. The mud factor of the surface wash has been neglected. And yet the muds (later shales) comprise much the largest part of the solid residue of disintegration. This solid disaggregated residue and the colloids associated with it are separated from the true solutions in large measure at the very start on their long journey to the sea. The true solutions are largely formed by waters that descend through the soils into the underlying formations and thus form the ground waters which pass by springs and seep into the streams, giving them their steady supply of clear water. This is the water chiefly analyzed and taken into account in reckoning the material borne by the streams to the ocean. The solid residue, the clays, silts, and sands, however, are only slightly removed by the gentler rains which soak into the ground. They are carried down to sea chiefly by the floods following heavy storms, or by the thaw waters of winter snows which form the spring freshets, or by flood stages from any cause. The turbid matter of these muddy waters contains a large part of the acid radicals with which the basic radicals of the true solutions were united in the parent rock and in the soils. While it is known that the muddy waters contain hydrous silicates of alumina and iron, partly colloidal and partly noncolloidal, together with finely divided siliceous silts and colloidal silica, full and exact information is lacking. Doctor Collins says that "the dissemination of silica in natural waters, particularly turbid waters, is one of the least accurately known of the determinations of substances present in appreciable quantities."[20] He adds that even "the exact state of the silica present in a perfectly clear water is usually not known. It may be colloidal or it may be present as a silicate radical." In addition to this—or perhaps the cause of it—investigation is embarrassed at the inland end of the cycle by the fleeting and irregular nature of the freshet stage, and by the rapid and intricate changes within the soils. The changes in the soil are so rapid in certain respects that F. H. King found it important to make his determinations of water-soluble solutions by means of an improvised laboratory in the field so that determinations might be

[20] W. E. Collins, chief of the quality of water division, U. S. Geol. Surv. Personal communication.

made as promptly as possible after the sample tube had taken the soil from its natural relations.[21] At the sea end of the cycle the recombinations of the acid radicals with the basic radicals seems to take place chiefly at the base of the turbid water as it is carried out over the concentrated sea solutions and diffuses into them. Before the acid radicals reach the bottom the reversing phase of the cycle has probably ended and a new cycle begun under suboceanic conditions. The experimental evidence in support of this conclusion is buried in a great mass of literature which relates primarily to other elements, particularly the elements that form plant foods, such as potassium, phosphorus, etc., and those that form precipitates such as calcium and magnesium carbonates, but when these scattered data are gathered together their combined import is sufficient to make clear the essentials of what happens.[22]

The present status of knowledge and opinion is summarized by the following quotations.

Doctor Truog writes:[23]

> The minerals or salts in soils consist largely of silicates. On weathering the bases are removed from the silicates, leaving acid residues or acid silicates. These acid silicates will react with salts like KCl and NaCl and remove the base and leave HCl in solution. When soil is treated with equal molecular strengths of these two solutions, the potassium is removed to a greater extent than the sodium. This is due to the fact that the potassium forms more insoluble compounds with the acid silicates than the sodium. Furthermore, silicates which have not had their bases removed will also react with these salts and exchange bases with them. For example, potassium chloride will react with an insoluble sodium silicate, in which reaction the potassium replaces the sodium and the sodium is left in solution as soluble sodium chloride. If an insoluble potassium silicate were treated with a solution of sodium chloride, some of the sodium would replace the potassium and some potassium would thus go into solution as the soluble chloride. This, however, would not proceed to as great an extent as the previous reaction, since the potassium forms a more insoluble silicate than sodium. In reading some of the literature on this subject one may get the impression that sodium is not retained by soils like the potassium, but this is really not the case; the action is merely relative. The potassium is retained to a greater extent simply because it forms more insoluble compounds with the soils.

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[21] Bull. 26, U. S. Dept. Agri. (1905), pp. 26–27.

[22] The following are among the more important early investigations:

Way, Jour. Roy. Agri. Soc., vol. 11 (1850), pp. 313–379; vol. 13 (1852), pp. 123–143; vol. 15 (1854), p. 491.

Eichhorn, Pogg.-An., vol. 125 (1854), p. 126.

Voelcker, Jour. Roy. Agri. Soc., 2d series, vol. I, pp. 289–316.

Kullenberg, Hoffman's "Jahres bericht der Agrikultur Chemie," vol. 8 (1865), p. 15.

Lemberg, Zeitschr. deutsch. Geol. Gesell., vol. 29 (1877), p. 483.

[23] E. Truog, soil chemist, Dept. of Soils of the College of Agriculture, University of Wisconsin. Personal communication.

Dr. Milton Whitney [24] writes:

The investigations of this bureau [25] show that the absorptive power of a soil resides almost wholly in the ultra clay or the colloidal material in the soil. This ultra clay is mainly a hydrous silicate of alumina and iron, with hydrated oxides of iron and probably alumina and absorbed calcium, magnesium, sodium, and potassium. It is of a colloidal nature, and can be separted from the soil in the form of minute droplets in dilute colloidal solutions which form into colloidal aggregates when the concentration is somewhat over 1 gram per 1,000 c. c.

The chemical analysis of the soil colloids which we have separated shows considerable amounts of lime, potash, soda, and other material which we believe to be absorbed in colloidal condition. We believe there is a distribution between the amount so absorbed and the concentration of the noncolloidal part of the solution. We believe also that the absorption of any one of these constituents such as potassium will be influenced by the presence of other salts such as sodium or calcium. Under all stable conditions there will be an equilibrium between the amount absorbed and the concentration of the surrounding liquid. Sodium chloride lowers the absorption of potassium chloride and calcium salts lower the absorption of potassium chloride. In general, soils and the colloids obtained therefrom absorb the basic ions much more readily than they absorb the acid ions.

According to Clarke the earth's crust contains 3.28 per cent of Na_2O and 2.96 per cent of K_2O. Thirty soils and the colloids obtained from the same collected by this bureau contained in the soil 1.59 per cent of K_2O and 1.45 per cent in the colloids. The soils contained on the average 0.77 per cent of Na_2O and 0.29 per cent in the colloids. These figures show very clearly the greater power possessed by the soil colloids to absorb and to hold back potash than they have for sodium.

A diffusion experiment with a soil colloid lasting over two months in which large volumes of distilled water were allowed to act showed a loss of 25 per cent of total K_2O and over 95 per cent of the total Na_2O.

There is no question that the soil colloids are able to absorb NaCl. This is shown by the ancient experiments of making sea water drinkable by filtering through soil filters.

Data and references examined show that under conditions of leaching by rain water where equilibrium conditions are changed potassium is largely retained by the soil but sodium is largely leached out.

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[24] Milton Whitney, Chief, Bureau of Soils, U. S. Department of Agriculture. Personal communication.

[25] These include numerous publications containing many analyses as well as special discussions, but as in all agricultural publications the constituents that most concern plant life receive most attention and data relative to sodium is incidental. The following may be cited:

Cameron, F. K., and Bell, J. M., "The mineral constituents of the soil solution," U. S. Dept. Agr., Bur. Soils, Bull. 30, 1905.

Cameron, F. K., and Patten, H. E., "The distribution of solute between water and soil," Jour. of Phys. Chem., vol. II, pp. 581–93, 1907.

Patten, H. E., "Some surface factors affecting distribution," Trans. Amer. Electrochem. Soc., vol. 10, pp. 67–74, 1906.

Patten, H. E., and Gallagher, F. E., "Absorption of vapors and gases by soils," U. S. Dept. Agr., Bur. Soils, Bull. 51, 1908.

Patten, H. E., and Waggaman, W. H., "Absorption by soils," U. S. Dept. Agr., Bur. Soils, Bull. 52, 1908.

Schreiner, Oswald, and Failyer, G. H., "The absorption of phosphates and potassium by soils," U. S. Dept. Agr., Bur. of Soils, Bull. 32, 1906.

Parker, E. G., "Selective adsorption by soils," Jour. of Agr. Research, Dept. Agr., vol. I, no. 3 (Dec. 10, 1913).

In the presence of much NaCl, as is found in sea water, ocean shore deposits would undoubtedly absorb considerable NaCl up to the point where the colloids were in equilibrium with the sea water. If the material were then formed into a shale and elevated to land areas, the induration would presumably destroy the colloidal properties, leaving the NaCl free from its colloidal entanglements, and with the change of the solvent from sea water to rain water equilibrium conditions would be expected to remove readily a considerable amount of the NaCl, while the K_2O would be largely retained on the weathering of the shale and the reformation of colloids resulting therefrom.

From these authoritative statements of present knowledge and opinion; from the early experiments of Way, Eichhorn, Kullenberg, Voelcker, Lemberg, and others, in mingling soils with salt solutions and in passing salt solutions through soils, and from many intermediate experiments cited by Sullivan,[26] there is left little ground for doubt that when the acid radicals previously separated from the basic radicals under conditions of very low concentration, again meet basic radicals under conditions of high concentration in the ocean off the mouths of the streams, reunion takes place in equilibrium proportions. The experiments of Lemberg are particularly instructive on this point. He treated potassium-aluminum silicates with sodium-chloride solutions of different degrees of concentration, and after thoroughly washing the solid material so treated found *that potassium had been replaced by sodium* in increased quantities as the concentration of the sodium solution was increased. Complete replacement of the potassium by the sodium did not take place, but only replacement to the degree required by the law of equilibrium. Now if, in addition to laboratory results, we recall that in former times salt water was freshened for use by passing it through soil, the periodic flooding of the border waters of the ocean by soil wash from the lands may be looked upon as a natural process of salt-water freshening. As there was wash from all the lands, and as the shales formed from the wash products are known to make up much the largest part of the sediments, the process was really one of great magnitude.

As the recombinations are divided among the constituents in accordance with the law of equilibrium, the sodium gets a smaller share than the potassium, but it gets a share. From the imperfect evidence one may guess that the sodium recombines to a third or a fourth of the extent of the potassium, but whether more or less than this proportion, it seems clear that enough sodium reunites with the acid radicals in their solid state to vitiate the use of sodium solutions as a criterion of age. This is as far as the present issue requires me to go. Doubtless other cycles follow in the sea and in the sedi-

[26] Eugene C. Sullivan, "The interaction between minerals and water solutions, with special reference to geologic phenomena," Bull. No. 312, U. S. Geol. Surv. (1907), pp. 7–62.

mentary beds, particularly when deformations take place or igneous and metamorphic actions follow, but we need not dwell on these.

The cycles of chlorine.—The climax of the solvent actions that enrich the sea is reached in the cycles of chlorine, but only a passing word can be given to these. The tenor of experiments with soils indicates that chlorine remains more persistently in solution than the sodium and associated substances. As the cycles of each substance spring from its own nature and the conditions it encounters, the very high preponderance of chlorine over sodium in the ocean finds its chief explanation in this more persistent solubility. Its proportion in average rock is only a conditioning factor and is not the chief controlling influence. When compared with sodium, which is much more abundant in the igneous rocks and indeed in the whole substance of the outer 10 or 20 miles of the earth shell, atmosphere, and hydrosphere included,[27] the logical conclusion is that the cycles of chlorine have always had a much larger liquid phase than those of sodium, and that this has been cumulative through the ages. Chlorine is better fitted than sodium to be used as a criterion of age, but even in this case there are formidable difficulties. Both sodium and chlorine and all the other constituents, as already noted, have their own histories which are difficult to disentangle. As Roger Bell neatly puts it: "There are as many histories to be written about the waters as there are kinds of sediment."[28] There would be an ocean highly charged with chlorides if there were no sodium in the earth at all. So there would be an ocean highly charged with sodium solutions if there were no chlorine in the earth. The status of the ocean at any time is simply the equation of the solution phases of the antecedent cycles of its constituents, all of which have passed through long, complex, more or less individual histories. In the tedious work of their disentanglement the older and simpler geochemical notions will not answer; the newer principles of chemistry, physics, and geology are indispensable.

Conclusions.—Our finding, then, in respect to the age of the earth from the geological viewpoint is this:

1. Estimates of time based on the well-preserved series of geological sediments will, when adequately corrected, probably fall into harmony with the revised deductions from paleontology, radio-activity, and astronomy, so far as these cover the same ground.

2. The distorted and metamorphosed terranes below the well-preserved series of sediments do not disclose the starting point of sedimentation. The sediments can therefore give no verdict on the *total* age of the earth; they are great enough, however, to show that the earth is very old.

[27] Clarke and Washington, ibid., p. 114.

[28] Personal communication.

3. The science of hydrogeology, of which oceanology is only a part, is not yet ready to render a verdict; it has more need of a court of inquiry than a place on the witness stand.

THE AGE OF THE EARTH FROM THE PALEONTOLOGICAL VIEWPOINT.

By John M. Clarke.

It falls to me to consider this knotty problem on the basis of the biological evidence alone, in so far as it is possible to disentangle this from its almost inevitable complication with geological accompaniments. In saying biological I mean, of course, biology with the time element generously admitted; that is, not the biology of the instant, the present, but the long biological panorama leading up to the present. Thus I am in a different case to some of my colleagues, for I presume it safe to say that life can have come into being only as a secondary potency in the evolution of force. Just what I mean is that the combination or interaction of physical energies of different categories did not produce the form of energy we designate as life till after a very long chapter of the earth's planetary history had been written. I may as well frankly say at the beginning that there can be little hope of arriving either at a reliable or an approximate conclusion as to the age of the earth through this paleontological channel, unless the study of the chronological development of life may in some way afford a measure of the rate of vital processes and thus the measure of some short span or infinitesimal fraction of earth history. This is a shadowy road and this presentation must resolve itself into consideration of such evidences as there may be for time-requisites in the consummation of evolutionary biological procedures, whether in gross or in detail. The bare statement of this fact in such vague form must carry with it an indication of the grave uncertainty of the results except to minds of the fourth dimension. I am not convinced that it is within the power, now or ever, of even the most refined understanding of paleontology, to accomplish this and establish such standards of measurements. Nor am I at all confident that the attempts which have been made to establish such rates of procedure could justify the great labor they have exacted, were it not for the important accessory facts they have elicited.

There seems to be no effective reason or very good philosophy in declaring, as some of our writers have been wont to do, that all life is one life. We seem to have really established the polyphylogeny of several races not only in the lower phyla of animals and plants, but among the vertebrates, and in the thought of competent authority, even to the inclusion of man, and we assign these like products to a differently governed and directed inheritance emanating from fixed

points in evolutionary history. This is an enlarging point of view in the interpretation of past life, and admitting its general effectiveness we can conceive and can justify a concurrence of physical energies which need not, and indeed should not logically, be restricted to some single outburst and some single definite moment in earth history. This intimation is that life itself may be polygenetic, though we would not have it interpreted as applying to the reiterative appearance of inceptive life through the ages, which is an old conception that still awaits its justification; it is rather only the precise implication of a terrestrial condition so controlled that by the intersection of the requisite forces life came into being at the *points* rather than at the point of such intersection—a crude way of stating it, perhaps, but it is an intimation of my meaning.

When we gaze upon some of Walcott's Burgess Pass fossils, see the extraordinary intricacy of their anatomy, as, for example, the crustacean Burgessia, with not merely the delicately toughened parts of its exterior, but the evidence of internal organs of great refinement, the lobulation and venation of renal organs; and, in the trilobite Neolenus, the multiplex delicacy of gills and swimming or walking organs, the effective impression is that, as between such creatures and their nearest allies and perhaps their offshoots of to-day, there is no difference in degree of specialization of structure, no progress in perfection of organic function. Indeed, we may even go further: modern allies of these creatures are in close straits of adjustment to their own physical surroundings, which are too often indicative of the surrender of progress, and to this I shall again make reference. But the Walcott fossils are from the Middle Cambrian, almost the oldest term in the whole long series of rocks in which life has been well preserved, and we here, in this year 1922 of the Christian era, are unable to find that any progress has been made in the structure of these creatures or along the direct line of their development and succession. Their successors in time and place have adjusted, readjusted, adapted, and readapted themselves without having produced a creature of their tribes which can be called a more intricate or a more perfect mechanism.

And yet what has gone on in that vast interval of time from then to now? The successive derivation of all intermediate types of life have come into being. The trilobite Neolenus, from the viewpoint of the paleontologist, stands for a tremendous conception of the vastness of time behind it. This inconspicuous thing, standing back behind us in the dim days of the Cambrian, stripped bare now by the arduous labors of its discoverer, reveals a creature so highly specialized that it must have commanded uncountable ages for its production by any such process of organic development as that to which we

paleontologists make our allegiance. The problem behind the Neolenus is that of having developed out of the unicellular expression of life, under favoring physical conditions and directive impulse, this intricate and closely functioning organism. How long did it take? I would like to put the problem to the experimental biologist: Given an organism with a full equipment of motor and sensory nerves and an elaborated digestive tract, with specific organs of circulation, reproduction, and of waste—is the distance greater from that starting point to the specialized creatures of the present, ourselves if you will, or from the nuclear cell (which we must hold to be not alone the seat but the radial point of life) up to that marvelously specialized creature? Starts are slow, progress to be secure must be deliberate, the momentum of the impulse must be acquired gradually, the passage from a protozoan to a metazoan means the crossing of a deep moat, the climbing of a high wall. But the directive once acquired, then matters may go forward with acceleration. On the basis, then, of the structure of this ancient trilobite alone, it is safe and probably necessary to answer that Neolenus was farther away from the beginning of life, very, very much farther away, in the highest probability, than we of to-day are from Neolenus.

This is a relative expression, but we can not be more concrete. The Walcott discoveries have lifted the veil from a scene in the panorama of life that was barely guessed before. In our previous general understanding there was, in the still earlier faunas, a group of creatures believed to be of simple structure and lowly place in the category of life; it was thought that with these simple things the caravan of life had got under way for its journey through the ages; and now we are compelled to believe that the journey was half over when this caravan first came under our eye.

It is not my part to make a review of statements and calculations of earth age based on the rates of sedimentation from the Cambrian time on to the present; but whatever these are, they may, from the biological point of view, reasonably be doubled and then increased by some improper fraction, if we are to reach a competent expression of the duration of the life day of extinct species—the zoëhemera, as I termed it many years ago, and of the sum of these which go to make a fraction of earth history.

It has not been the practice of students of evolutionary paleontology to raise the question as to whether there were time enough available for the production of the succession of results which pass under their eye. Such an attitude would of itself be highly unphilosophical, and only a natural inquisitiveness or curiosity quite unessential to the real philosophy of the succession and purpose of life has led to the occasional investigation as to the possible time rate of evolutionary processes under historic and under natural conditions.

We are not the makers, but the users, of time. There have been stages in the history of our science when we have been treated gingerly by astronomers and physicists in the allotment of time, but now that our colleagues in celestial mechanics are heaping upon us their munificence in the prescription of this heavenly commodity, we are content; and the interpreters of radiochemistry—we thank them for giving us what we already had. There is time enough. So much, indeed, that to absorb a needful share of it into the philosophy of the evolution of life actually requires of us a revision of our conceptions.

I should, I think, take passing notice of the fact that the problem as to how species have originated (one from another, with or without the help of mutations, variations, or variants—the problem of the factors which have controlled their production) does not belong to paleontology. Bateson, speaking recently at Toronto, has expressed the conviction that after the nearly three-quarters century since the publication of Darwin's Origin of Species we are still in doubt and darkness as to the causes of the origin of species. Incautious as it seems, that expression would still be a hopeful one if it means that in this relatively brief period the study of this theme, stimulated by Darwin, has led to the elimination of an extensive array of supposed factors, so that if the buried treasure, if it is really the treasure he has thought, has not yet been found, at least some of the brush has been cleared away from about the place where it lies hid. Both laborers in the field of living nature and those delving among the past creation see the engrossing fact of evolution, but see it out of different eyes; the former perhaps as one would see a vast throng gathered together to acclaim a momentous event, a great victory or a high armistice; the latter as an endless army marching by, its vanguard already out of sight in the mists of the horizon, stragglers along the way falling back or giving up in hopelessness, while the interminable procession ever emerges out of the shadow.

Once upon a time, when Walcott was first bringing out his wonderfully specialized Cambrian fossils from the Burgess shale, I said to the discoverer in a jocular way, "Keep on and you may find the remains of a Cambrian man." In the recent address referred to, Bateson ventures more solemnly into this field. "It has been asked [I am quoting] how do you know, for instance, that there were no mammals in paleozoic times? May there not have been mammals somewhere on the earth, though no vestige of them has come down to us? We may feel confident there were no mammals then, but are we sure? In very ancient rocks most of the great orders of animals are represented. The absence of others might by no great stress of imagination be ascribed to accidental circumstances." Considering that these remarks were made in the presence of a great body of

scientific men, among whom were paleontologists, I fear the speaker neglected to do what he should have done and as Artemas Ward was wont to do in like case, for in no evidence from any quarter, whether it be of biology, geography, geology, meteorology, oceanography, or psychology, is there the slightest justification for seriously embalming such a fancy in a scientific address and sending it abroad in the world for the daws to peck at.

We must fasten our gaze upon such impressive evidence as can now be adduced of the duration of time required in the attainment of organic specializations, and let me supplement those I have given by others taken from the plant world. Casting up the evidences that have been adduced by paleontologists and paleobotanists, I think the footings show very positively a large balance of argument in favor of the great conception that the life of the land has emerged from the sea. I believe it may be said, on behalf of paleontologists generally and their broader deductions, that these are happy in the harmony of their conclusions in this matter after having experimented with and checked up alternate conceptions.

The broader lines of evolutionary derivation and the best weighed deductive propositions seem to intimate a convergence of the life lines back to the sea and a radiation from it. The inception of life was the most solemn moment in the history of the universe. We invite certain astronomers to refrain from further speculations and presumptions as to life in other worlds, and followers of Arrhenius from pursuing life spores through interplanetary space. These notions seem to be very exciting to the emotional public and there is indeed no shred of evidence of these things, no matter what physical conditions may be predicated of other worlds than this. So far as the evidence of outstanding facts and major probabilities goes, life is confined to the earth. Into this solemn event, the birth of life, the interaction of the forces requisite to emergence, we shall not here attempt to pry. We look back, then, to a primitive period of life in the sea, the Plankton epoch, the place and stage of life's emergence, the surface life; followed by a Benthic epoch, the secondary stage of development in which the living forms had found the shallower sea bottoms and thereupon began their adaptations and more rapid evolution.

I shall now borrow freely the brilliant conceptions of Church, the British paleobotanist, as to the procedure among the plants thence forward from the sea to the land, an act which implies time in impressive measures and yet an act which we know has reversed itself in later geological times, at least among the animals, with nostalgic energy and must again and again have shown a like reversion in both the animal and in the plant world. We see suggestions

of these reversionary movements among the Amphibia and the Mollusca and many Mammalia, and it seems highly probable that a more exact knowledge of extinct life will establish these suggestions and awaken others.

The Plankton epoch, says Church, gave rise to the first encysted flagellate plants which, under conditions of the Benthon, developed multicellular thallus, tissues and organs of special function and a reproductive mechanism contrived so as to minimize waste. Then followed the epoch of the land flora brought on by the transmigration of highly developed algæ which in fact "appear to have been more highly organized than any single algal type at present known to exist in the sea." "The algæ of transmigration may be * * * said to have combined the best features of the known great conventional series of marine phytobenthon." "The origins of all the main successful adaptations of the land are to be traced down to the benthic phase of the sea." In this impressive statement we are confronted by the quality of the plant life at its emergence from the sea.

Now as to the period of its emergence, of foremost importance to our present consideration, Thomas C. Chamberlin in 1913 directed attention to the fact that the pre-Cambrian rock complex is divided into earlier and later stages on the basis of the degree of disintegration of the exposed rock surface. In the lower division there is an immature disintegration which implies partial decomposition, but the mature disintegration of the later division implies, he says, "some restraining agency that held the rock in place while the slow weathering completed its work." "This view favors the existence of a vegetal covering of the land as far back as this period."

Church, therefore, has a well-found argument when in the presence of this fact of pre-Cambrian weathering he intimates that it was with the uplifting and exposure of the primary rock to the air that "the marine organism was brought into direct association with atmospheric air and subaërial environment to mark out new lines of progression to still higher and more strenuous forms of land life, though these are again necessarily expressed in terms of preceding organization and mechanism." The point to be made here is that with the earliest lifting of land from the sea, benthic algæ of advanced structure, "the remarkable algæ of transmigration," as he has characterized them, got their foothold on the land. "The evolution of the land flora was a phase of transmigration in *situ*" and did not involve a preliminary landward migration by the way of fresh water, "the biological factors being exposure to more or less desiccation and the removal of the food solution." "The few races that survived only did so by pressing to the utmost any principles of economy in

reproductive output that they may have previously initiated," such as oögamy and fertilization in *situ*.

The picture presented by this line of carefully founded reasoning is even more impressive in its demands upon time than the argument we have presented from animal life. It is summed up thus: Plants of complex organization and function—deductively of higher organization than can be to-day found among the algæ—had worked out their attainments before their arrival on the land, and probably this organic achievement, not surpassed in the seas of to-day, was accomplished at a stage in earth history long before the Cambrian epoch brought with it the tangible evidence of the complex animals. The argument from the plants is more highly deductive than that from animals, but its steps are logically taken from effect to cause, and in its presence we must stand uncovered at the inconceivable lapses of earth time through which these transmigrant plants were slowly working out their organization in the waters when there was no permanent land—a period of time which must have been longer than all time that has passed since the emergence of the Laurentian or the basal rock complex of the great shields of the earth.

II.

If we are prepared to concede the steadily increasing weight of evidence of the polyphyletic origin of genera which recent researches have indicated for so many different groups of life, and can compel our conception to grasp the duration of the vast unrecorded past of life history, there remains another phase of the paleontological record which in part emphasizes and in part serves as a check on this conception. It has fallen to me to study the earliest recorded expressions of dependent life—that is, the beginnings, so far as we can find them, of such consociations of animals as we are wont to designate as parasitic, mutualistic, and symbiotic, wherein one creation has depended upon or adjusted itself to the life functions or habits of another, or has sought mechanical protection at the cost of its own locomotive independence. Two very obvious facts seem to stand out as a result of these inquiries: (1) That these interdependent conditions with which the living world is rife to-day, in passing backward to the early stages of Paleozoic time, become palpably fewer; indeed, while such conditions are well marked in some groups and common in others during the middle and later Paleozoic, they are very unusual in the earlier stages and in the Cambrian fauna are little more than suggested. (2) This dependent state seems with reasonable clarity to be resolvable into an original loss of locomotive independence, a willingness to be fed rather than to feed, an adaptation to an easier mode of life. The commanding percentage

of the Cambrian fauna belongs to groups against which the charge of surrender of locomotive independence can hardly be laid, though inclusive of groups of animals which in later stages did become infected with the loss of independence, but still in a capital sense embraced those whose independent living was unimpaired.

These considerations I have analyzed elsewhere in some detail and their significance is this—that the degeneration of life (for dependence of necessity implies degeneration of physiology) has been a process attendant upon and of course influencing evolution, but apparently limited in its effects to that part of the procession of life which comes under our actual observation; that is, since the days of the free and independent faunas of the Cambrian. If this is an approximation to the truth, as we believe it to be, then in a broad sense the real vigor of life, which established the major branches and laid down the plan of all future ages, was dominant in its purity in the ages before the beginning of the life record in the rocks. How often the student of the past of the earth has exclaimed at the wonder that man came through to his excellence in a world permeated with ever-increasing conditions of degeneration.

III.

With such propositions as the foregoing we are confronted by an impressive requirement of time necessary to the development of life on the earth. It is a requirement that seems to roll back and ever backward into the undifferentiated ages of our planetary history. It is a magnitude that takes on proportions before which the outstanding estimates of time based on processes of rock building would seem to dwindle, and it partakes more and more of the magnitudes in which the radiologist has been wont to speak. The question for us now is whether our present knowledge affords any basis for an estimate or calculation of this time or any part thereof into a concrete expression. If it were possible to estimate by any or all approaches, the length of the life of a single extinct species in any part of the world, there would then lie a possibility of determining what fraction this given quantity might be of the whole. For more than two generations the evidence has been sought, paleontologists endeavoring first to establish the endurance of a given or index species as the basis of a geologic or stratigraphic element—a zone.

Into the discussion of the zone—its meaning in time and space—has entered a very long list of eminent names in the science. The zone has been looked upon as a sedimentary element in which a datum species slowly coming to its acme suddenly culminates and abruptly disappears; as such sedimentary unit in which not a species, but a mutation, or an entire fauna rises and falls. To Oppel the zone was a space unit. Buckman has embodied the time conception of the

zone in the word *hemera*. The double combination of time and space makes a *biozone*. The time unit has also been termed *sæculum* by Jukes-Brown, *moment* and *phase* by the International Geological Congress. In the recent summary of these expressions and their interpretations as given by Diener, in order to determine a proper basis for his discussion, he employs the term zone for the spatial, that is horizontal and vertical distribution of a fauna, whose time is a moment.

The whole interpretation of these conceptions centers upon the origin and endurance of a mutation, which in the proper paleontological sense is a departure from a recognized species toward and into a unit which, by determinate action of the genes producing variation, will become another species. That is to say, the mutation is a clearly recognizable entity in paleontology, is the bridge crossing from species to species, the connecting link which establishes the continuity of the chain. Apart from considerations of physiology only, the paleontologist sees no further occasion for debating the existence of connecting links or of passages from species to species, or as to how species originate. The mutation is the departure from the one, seeking adjustment and failing, or seeking and finding it in what must be recognized from accepted standards as a distinct specific form, a different species from its parentage. But when it comes to a matter of determining the rates, the time measure of these changes under varying and all conceivable physical conditions, the pursuit seems to us hopeless, hopeless a priori, hopeless in observation. There are species that have held their own without change through the ages—"immortal types" they have been called; and there are others which have yielded so rapidly to change that their evolution is explosive. The same facts are true of *groups* of animals; and for the entire organic world there have been earth-wide periods of long stagnation as well as of rapid intensive change. So long as an estimate of the age of the earth rests on evidence of the rate of change or adjustment in organisms through the acquisition of new characters, we may as well abandon the attempt to express it in concrete terms and satisfy ourselves that for the development of life the duration of that fraction of the earth's history is beyond human expression.

THE AGE OF THE EARTH FROM THE POINT OF VIEW OF ASTRONOMY. (ABSTRACT.)

By Ernest W. Brown.

Astronomical evolution is considered under three heads: First, that method of observation in which it is assumed that all stages in the process are visible in the sky and so can be traced step by step.

Second, physical theory, based on well-known laws such as those of gravitation, heat, etc. Third, pure speculation. When we attempt to apply these methods to the solar system we find a complete absence of any observational evidence from the first point of view, because we have no stellar systems sufficiently near for us to detect planets if such exist. Thus evolution in the solar system is mainly a mixture of physical theory and speculation.

All theories of evolution use the idea of contraction under gravitation, which in general causes a gain of heat and of angular velocity. The chief differences between the theories consist in the forms of matter which are assumed to come into existence under the operation of the process of contraction. Laplace imagined that a planetary nebula contracted and in the course of the process left behind rings of matter which later condensed into planets. Roche showed that under certain conditions matter will be thrown off along the Equator. G. H. Darwin and Poincaré developed the processes of fission from which it was hoped that planetary bodies might be shown to have developed through successive divisions of the central body. Later workers at the theory, and particularly Jeans, have proved that this hypothesis is very improbable for planetary evolution on account of the fact that in this process of division the masses should be of the same order of magnitude and not, as in the case of the planets, of very different orders of magnitude. It has, however, been applied with considerable success to the evolution of close double stars. Finally there are the tidal hypotheses in which the matter is supposed to have been drawn off by the close approach of some second body which later moved away. Each of these hypotheses has many objections. But it may be stated that from these points of view we can learn nothing definite or even approximate about the age of the earth.

Another method of approach is through observation of the present condition of the bodies in the solar system. For evidence we have eight major planets, but it is very doubtful whether from so small a number we can deduce any results of value. In fact, it is now well known that differences in mass may produce very different consequences in the history of bodies. Thus arguments drawn from the moon, Mars, Venus, or the other planets have never inspired very much confidence.

Still another method is a consideration of the present condition of the earth combined with the theory of contraction and subsequent loss of heat. Here we are on somewhat firmer ground, since we have many observations which give information concerning the interior condition of the earth. Amongst these may be mentioned the values of the mean density and the surface density, the phenomena of precession, nutation, etc., the measurements of earthquake and seismic

waves, and measurements of the rigidity of the earth by various methods, and more particularly by that lately developed at Chicago by Michelson and his colleagues. From these phenomena we know with fair certainty that the earth *behaves mechanically* like a solid body which has approximately the rigidity of steel. It is sometimes assumed that this shows that the interior of the earth consists of matter which under surface conditions of pressure would be solid. Unfortunately the argument is doubtful, because we know nothing of the condition of matter under the pressures which it experiences at depths of 100 miles or more below the surface of the earth. It is, therefore, impossible to argue with any security concerning the temperature conditions in the interior of the earth from these observational data. Lately, Jeffreys has shown that under almost any theory of evolution the earth must at one time have been sufficiently hot so that all its materials were in a liquid state, understanding by this latter phrase, a state liquid under surface conditions of pressure.

Thus the astronomical evidence which can be furnished as to the age of the earth is practically nil, and one must turn to methods outside the range of the astronomer's work.

A further difficulty may be mentioned. Evidence is accumulating that there is widely extended diffuse matter in space, some of which is visible and some of which is only evident on account of the obscuration of light which it causes. It therefore seems highly probable that the solar system in the course of several hundred million years may have passed through one or several such clouds. These would have effects, which from theory are well known, such as diminishing the mean distances of the planets from the sun, the circularization of their orbits, possible changes in the total angular momentum of the system, and other effects, such as the possible formation of comets and the production of glacial and interglacial periods. At present, however, the consequences of this hypothesis are still in the range of speculation and need to be worked out in considerable detail before any arguments can be built on it. It may, however, be stated that such a hypothesis would have the general tendency of increasing the age of the earth as estimated from other sources.

THE RADIOACTIVE POINT OF VIEW.

By William Duane,
Harvard University.

In estimating the age of the earth one should measure the time that has elapsed by some process in nature that takes place in one direction only and that does not change its rate when conditions (temperature, pressure, etc.) alter. In most of the estimates of

geological periods of time that have been made the "clocks" employed do not fulfill these conditions. Estimates based on the temperature of the earth or of the sun, for instance, can not be reliable, for the temperature of a body may fall or it may rise. Further, the rate of change of the temperature depends upon a variety of conditions, such as the amount of energy radiated, the supply of energy to it, etc.

Attempts have been made to deduce the age of certain minerals from the appearance of little round marks in them, called halos. These halos are supposed to be due to radiation from minute specks of radioactive matter at their centers. The colors produced by radiation in transparent substances depend to a considerable extent upon the temperature, so that no very great weight can be put upon geological periods of time estimated by means of halos.

There are, however, other radioactive processes the rates of which do not, so far as we know, depend on the temperature or the pressure nor upon any other physical or chemical state.

During the last 25 years a large number of radioactive transformations of one chemical element into another have been discovered. Students of the subject agree that these transformations take place in one direction only, i. e., from an element of higher atomic weight to an element of lower atomic weight. Further, nobody has been able to alter the rate of a radioactive transformation by any process whatsoever, although numerous attempts have been made to do so. These radioactive changes, therefore, seem to offer a reliable means of estimating certain periods of time.

Among the radio-active changes appear processes in which the metal uranium transforms itself through successions of intermediate stages into the metal lead and into the gas helium. It does not seem necessary to describe in detail these series of transformations at this time. Descriptions of them may be found in the literature on radioactivity. It suffices for our purposes to say that the rate of transformation is such that 5 per cent of a quantity of uranium changes into lead and helium in about 370 millions of years.

We find uranium, lead, and helium associated together in a great many minerals and it is natural to suppose that the helium and the lead were produced by the disintegration of the uranium during the past ages. Further, if we determine the relative amounts of uranium, lead, and helium in a mineral we can form an estimate as to how long these chemical elements have been in contact with each other. Estimates of this kind that have been made from the quantities of helium in uranium ores vary between 8 and 700 millions of years according to the locality from which the ore came. Since some of the helium (it being a gas) may have leaked out of the ores these

intervals of time must be regarded as minimum estimates. The uranium and helium must have been in contact with each other for at least as long as the periods mentioned, but they may have been together for much longer intervals of time.

Calculations based on the quantity of lead in uranium ores vary from 340 millions to 1,700 millions of years, according to the locality from which the ore is obtained. In this case another complication appears. We have learned to distinguish several different kinds of lead from each other. The various kinds of lead have similar chemical properties but differ from each other in their atomic weights. All the different kinds of lead do not come from uranium; only lead of atomic weight about 206 may be regarded as produced from uranium. Until, therefore, we have determined exactly what the atomic weights of the lead in the various ores really are, we can not be sure that the lead came from the uranium. We can assert, however, that there is no more uranium lead in a given uranium ore than the amount of lead actually found. Unless, therefore, the atomic weight of the lead in an ore has been actually determined and found to be about 206, we must consider the estimate of the age of the ore as a maximum estimate only. The lead and uranium can not have been in contact with each other for a period of time longer than that calculated from the known rate of transformation of uranium into lead.

The atomic weight of the lead in a few ores has been found to be very close to 206. In one of these the age of the mineral has been estimated at a little over 900 millions of years.

The calculation of the age of uranium deposits by means of radio-active data rests upon the laws of nature as we now believe them to be. It would be a waste of time to speculate on future discoveries (new radio-active elements, for instance, or alterations in the rates of radio-active processes) or on a possible evolution of natural law.

The ages calculated from radio-active data represent the length of time during which we may suppose the chemical elements to have been in more or less mechanical contact with each other. They do not represent the time that has elapsed since the earth may have reached a state capable of supporting organic life as we now know it.

HOW DEEP IS THE OCEAN?

By C. G. Abbot.

Not everybody who laughed over the "Connecticut Yankee in King Arthur's Court" knows why its author called himself "Mark Twain." To know that, one should read his earlier book, just as funny in spots and far more interesting, "Life on the Mississippi."

Here's how they took the conceit out of a cocky young cub pilot by leaving him alone to navigate one of the deepest places on the Mississippi and scaring him with false soundings.

Captain and Mate sang out instantly, and both together:

"Starboard lead there! and quick about it!"

* * * * * * *

Then came the leadsman's sepulchral cry:

"D-e-e-p four!"

Deep four fathoms in a bottomless crossing! The terror of it took my breath away.

"M-a-r-k three! M-a-r-k three! Quarter-less-three! Half twain!"

This was frightful! I seized the bell-ropes and stopped the engines.

"Quarter twain! Quarter-twain! *Mark* twain!"

* * * * * * *

I was quaking from head to foot, and I could have hung my hat on my eyes, they stuck out so far.

"Quarter-*less*-twain! Nine-and-a-*half*!"

We were drawing nine!

* * * * * * *

I flew to the speaking-tube and shouted to the engineer:

"Oh, Ben, if you love me, *back* her! Quick, Ben! Oh! back the immortal *soul* out of her!"

I heard the door close gently. I looked around, and there stood Mr. Bixby, smiling a bland, sweet smile. Then the audience on the hurricane deck sent up a thundergust of humiliating laughter.

* * * * * * *

For months I so often had to hear a phrase which I had conceived a particular distaste for:

"Oh! Ben, if you love me, back her!"

This kind of a scheme of hand sounding is well enough for water so shallow that it is dangerous, but what good is it for sounding the ocean depths that average 2,000 fathoms (12,000 feet), and in many

places run to 3,000 fathoms? Indeed there is one sounding by the U. S. cable ship *Nero*, far out in the Pacific, of 5,269 fathoms, which lacks just 66 feet of being 6 miles. So Mount Everest, the highest mountain in the world, could be turned upside down there without hitting the bottom by half a mile.

For purposes of navigation, the most important thing is to know where the shallow places are, and just how shallow they are. Governments maintain coast and hydrographic survey organizations for this purpose. All of the approaches to important harbors are mapped quite as carefully as the land, in order that ships can go safely. Our own country and island countries like Great Britain have had an immense task in sounding and surveying their enormously long coast lines.

Until now the depths less than 20 fathoms (120 feet) have usually been observed by letting down by hand from stationary boats weights called "leads" attached to cords. The lead is hollowed out at the bottom and filled with tallow so as to bring up a little sample of the bottom, and prove that it has been reached.

For depths over 20 fathoms, steel wires are used instead of cords, and special machines for unreeling and reeling up the sounding wire are employed. As the depths increase the time required increases, too. Of course the ship must be as stationary as can be during the letting down of the lead. If the sounding apparatus is at the stern she can, of course, get under way as soon as the bottom is surely reached. With enormously great depths it would be a little difficult to tell just when this time came, if the lead was not extremely heavy. For what with the weight of the wire, the surging of it to and fro under the influence of waves and currents, the difference between resting on the bottom and not would be inconspicuous with a light lead. A device was therefore invented so that as soon as the wire slackened, due to the resting of the lead on the bottom, the sinker separated. Thus heavy sinkers could be used without having to pull them up again, and the fact that they were detached proved that the bottom was reached.

There is another sounding device which can be used at depths less than 100 fathoms which does not require the ship to be stopped and is used in navigation. The lead contains a glass tube closed at the top and faintly etched inside according to Benedict's scheme with a screw of about 40 threads to the inch. As the lead sinks deeper and deeper the pressure of water compresses and forces the air back and back in the tube, and wets the etching so that the exact amount of compression of the air is shown. This is read off on a scale which indicates the depth. Of course with the ship moving, the bottom can be surely felt by the twitching of the cord.

It requires from 15 to 25 minutes to get a sounding of 1,000 fathoms for surveying purposes, 45 minutes for 2,000, 75 minutes for 3,000, and 5 or 6 hours for a depth like that found by the *Nero*. This shows what a time-consuming, costly business it is to learn about the bottom of the ocean. In fact it is so costly that little is known compared with what should be.

The most famous scientific expedition of all history was undertaken by the British ship *Challenger* which started on a three year's cruise at Christmas, 1872, and returned in May, 1876. She spent nearly a year in the Atlantic, several months in the Antarctic, and over a year in the Pacific. Besides the navigating officers, she carried naturalists, chemists, geologists, and physicists. Not only soundings but dredgings of the mud of the bottom, deep-net hauls of fishes and deep-sea animals, temperature measurements, carbonic acid and salt measurements, and many other studies were carried on every day. The results filled 50 great quarto volumes, and, like Columbus, discovered a new world peopled by creatures even stranger than he found in America.

The United States and many other countries have also engaged in this interesting ocean study. Notable voyages of scientific discovery were made by the late Prince Albert I of Monaco. He was a scientist even more than a prince, and not only devoted great sums to building and equipping special ships for ocean investigations but went to sea himself and took a vigorous part in the actual investigating. He received the Murray Gold Medal for his work on oceanography from our National Academy of Sciences in April, 1921, and lectured at Washington on his work.

But of what good is it, says some one, this making difficult soundings and hauls way out to sea? In the first place, all knowledge is good to take away ignorance and superstition and point the way to new discoveries. When one throws down a handful of seeds, he can not tell which ones they will be that will survive and give the hundredfold increase. So it is with discoveries. No one could have predicted in 1830 that Faraday's and Henry's experiments on magnetic effects of electric currents would have grown up into the telegraph, telephone, dynamo, and all modern electrical installations.

But soundings are not only valuable as interesting knowledge in themselves. They have a bearing on many other scientific problems of the tides, the condition of the earth in past geological epochs, the causes of ocean currents, the climate, and others. More directly still, they are indispensable for submarine cable laying. Cables are costly things, and repairing of them is a costly business. It makes

much difference as to the lengths required and the costs of laying and repairing what kind of the ocean floor they are to lie upon. What a foolish business, for instance, it would be to lay a cable into a hole like that sounded by the *Nero* in the Pacific, if it could just as well be avoided.

The matter is not even altogether out of the field of romance. Once in a while a new island appears or an old one sinks. Coast lines go up and down, slowly it is true, but perceptibly enough to

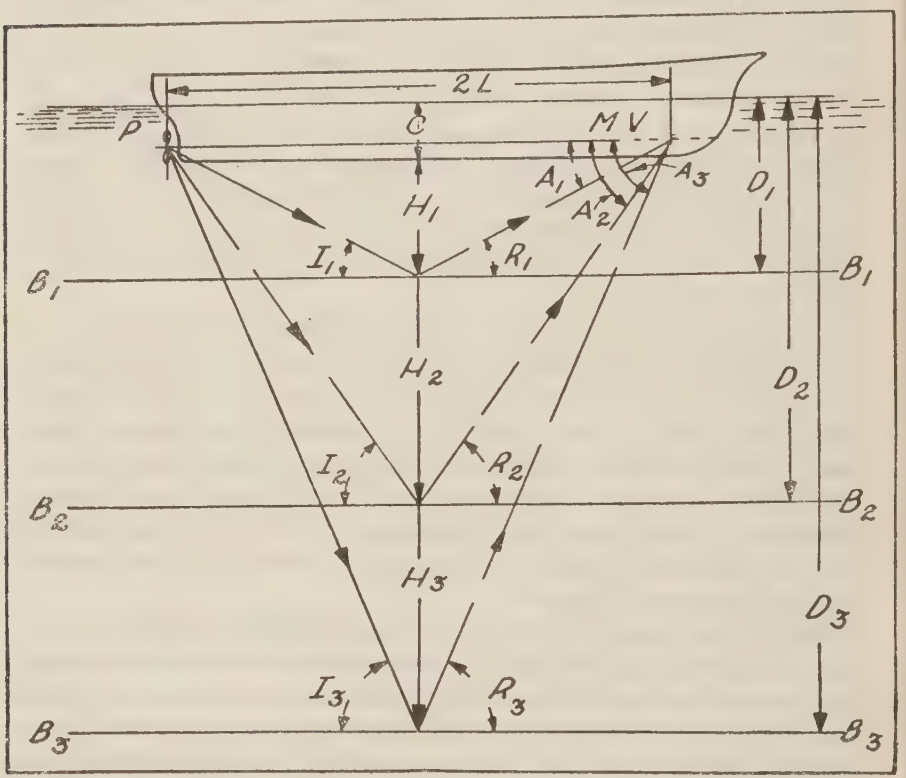

FIG. 1.—Diagram showing the method of taking depth soundings with the hydrophone.

illustrate for us those grand natural processes of uplift and erosion which laid down beds of marine fossils now thousands of feet above sea level as at the Grand Canyon of Arizona. Plato in his "Timæus" tells a tale some Egyptian priests told him of a lost island called "Atlantis" as big as Asia Minor and Libya together which ages before had existed "beyond the Pillars of Hercules," which meant out in the Atlantic west of the Straits of Gibraltar. Plato even described the ideal commonwealth and the powerful armies of Atlantis and its conquests along the shores of the Mediterranean. But the island, as the priests said, had been overwhelmed by the ocean long before,

and lost, leaving for a time dangerous shoals to mark its sunken place.

Recently, as the result of attempts by our Navy during the war to locate ships and submarines by the sounds they make, the art of ocean sounding has taken a great step forward. A device called the "MV hydrophone" has been invented and perfected to such a high degree that in favorable cases sounds coming as far as 20 miles can be heard and located in direction. By this ingenious device, and modifications of it made under the direction of Dr. H. C. Hayes, of the Navy, it has become possible to locate by sound ships, shoals, precipitous shores, icebergs, and "sound beacons" and to communicate by sound from ship to ship. Not only so, but a means has been perfected and applied with the most complete success whereby the depth of the ocean can be measured continuously by a vessel proceeding at good speed on her course.

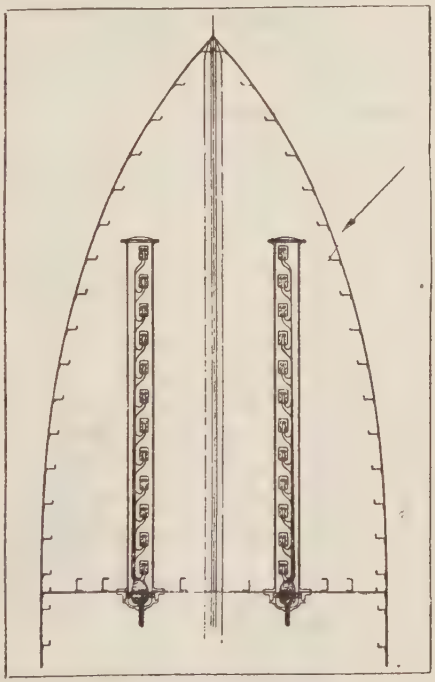

FIG. 2.—Section of bow tank showing relative location of port and starboard receiver lines and intervening sound screens.

Just as our heads have two ears, by means of which we judge of sound directions instinctively because it takes sounds from our right a trifle longer to reach the left ear, and vice versa, so the MV hydrophone has two sets of sound receivers placed one on each side deep down attached under the ship's bottom. As it is not convenient to turn the ship toward the sound, as we do with our heads, until the sounds reach the two sets of receivers simultaneously, an electrical arrangement is provided for retarding the sounds from receivers which get it first until all come in unison into the double telephone headpiece of the observer.

This retardation principle is carried still further, for the two groups on either side of the ship each contain 12 receivers spaced 12 inches apart in a row parallel to the ship's length. Hence it is only found sounds coming in exactly at right angles that there is no difference in times of receipt by the separate instruments of each bank. Thus each set alone by itself is a direction finder, but it takes both

together to tell whether the angle of direction found means to right or to left of the vessel. That can be told from the relative loudness on the two sides.

The receivers themselves have membranes like a drum or a telephone, and microphones attached which are connected through the

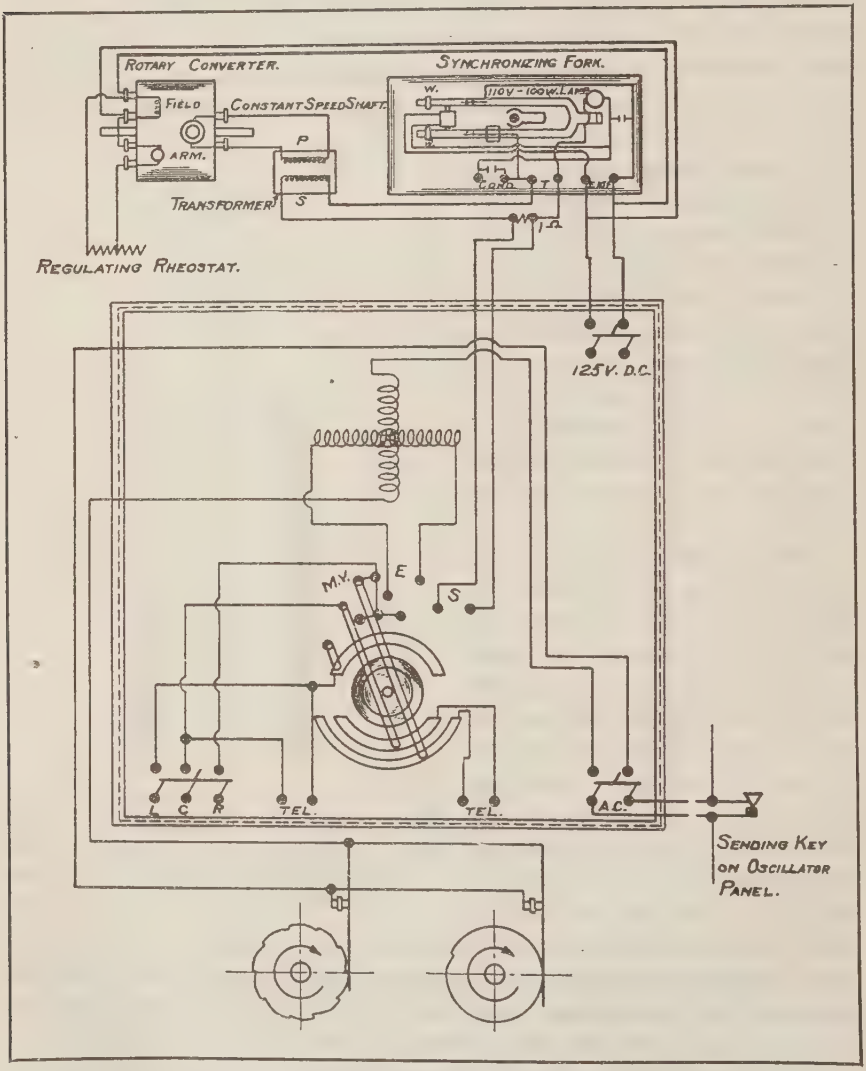

FIG. 3.—Wiring diagram of depth finder.

electrical compensators for retarding the sounds, so that they join to operate the telephones on the observer's head. Their arrangement and connections are shown in figures 2 and 3.

Such hydrophones can hear the propellers of their own ship or the sounds of a sound-signalling apparatus located at the stern. Propeller sounds are of low pitch, and so are other water noises like the

splashing of waves. Sounds of extremely high pitch are therefore better for signalling purposes. Not only can such signals be heard directly but the echoes of them from the bottom of the ocean can be heard too. Therefore it is easy to see in principle how by measuring the angle from which the echo sounds come up to the receivers one could determine the distance to the bottom. For with sound as with a billiard ball (played without English) the angles of the path at the reflecting surface are equal. Knowing the ship's length and the angle the sound appears to come from, it is therefore easy to calculate the depth. But this scheme is good only for depths less than two or three times the ship's length. Beyond that the errors of measuring the angles produce too much error in the result.

Doctor Hayes has worked out another scheme for greater depths. This depends on measuring the time between sending the signal and receiving its echo. Sound travels 800 fathoms per second in water. Hence it can easily be seen that a stop watch would not be accurate enough, for an error of one-fifth of a second would mean the half of 160 or 80 fathoms in depth. An indirect process is used. Sounds are sent out at equal intervals. A very accurate and controllable mechanism is used so that not only are the intervals between the signals exactly equal but the interval can be varied in length between wide limits. It will be seen that as the interval is changed it can be arranged so that one ear will hear the series of sounds directly at the same instant that the other ear hears them through the hydrophone as an echo from the bottom.

If the time intervals are read off from the scale of the sending machine, and if one could be sure that the coincidence was caused by the interval being just long enough for the sound to go to the bottom and back, that would be enough. But it is plain that, by speeding up, the interval could be shortened so much that there would again be a coincidence. Again it could be shortened still more till a third coincidence came, and so on. But it is clear that the lengths of these several intervals that gave coincidences would be as 1 to 1/2 to 1/3, and so on. From this it is easy to tell just which coincidence we are using.

This method of measuring depths has been made exceedingly accurate for all distances above 40 fathoms, and so it joins onto the other one to cover all ocean depths. The first big test of it on an actual cruise was made in June, 1922, on a run of the U. S. destroyer *Stewart* from Newport, R. I., to the Straits of Gibraltar. This voyage was made in nine days. During it and while proceeding at usual speed, several hundred soundings were made as shown on figure 4. The depths observed ranged from less than 100 fathoms during the

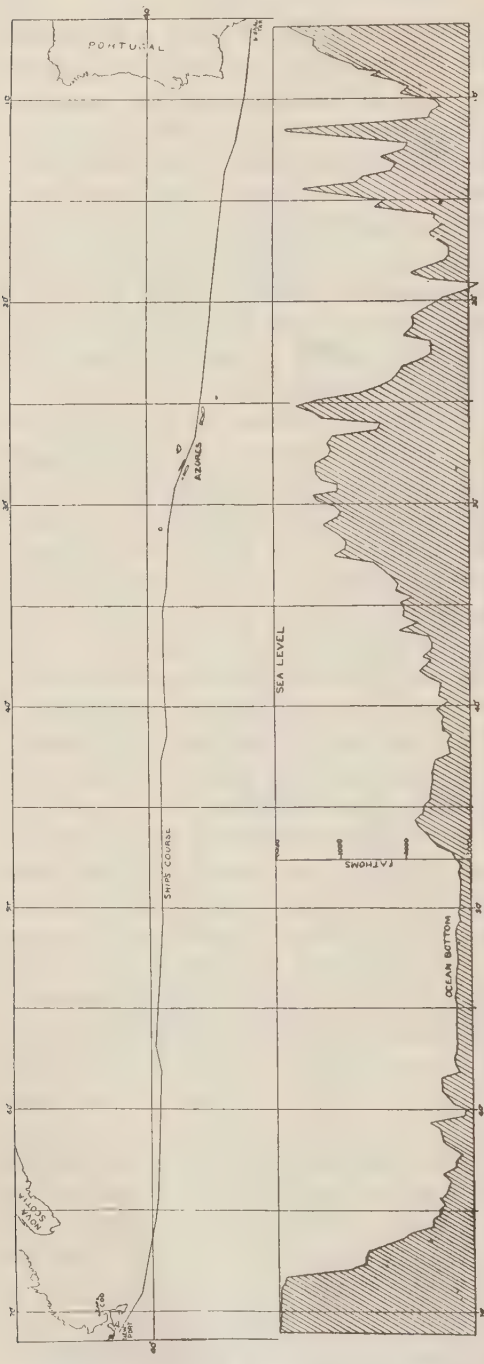

FIG. 4.—Depth of the Atlantic Ocean as obtained from cruise of the U. S. destroyer *Stewart* from Newport, R. I., to the Straits of Gibraltar, in June, 1922.

first day to 3,200 fathoms found at one spot near the end of the voyage. About 1,200 miles west of the Straits of Gibraltar they ran over a comparatively shallow region, about 500 miles wide, where the depths averaged less than 1,000 fathoms. If we could imagine this part elevated as much as the plateau at the Grand Canyon has risen out of the sea, we might see again Plato's lost island of Atlantis. Wonderful pinnacles were found, the like of which are hardly duplicated in abruptness by mountain ranges anywhere on land.

This new and powerful method of making soundings was seized upon immediately for scientific purposes. Great interest had been growing in recent years in volcanoes and earthquakes, their causes and effects, and the means which may be found to foretell them. Those who remember the San Francisco earthquake will not be surprised to know that roughly parallel to our western coast there lies a region liable to disturbance from earthquakes and volcanoes.

Beds of lava not so very old, as geology counts age, may be seen in various parts of California, and for some years Mount Lassen has been somewhat active as a volcano. Others of the peaks in northern California, Oregon, and Washington show evidences of volcanic origin. As far north as Alaska, and all down through old Mexico and the western countries of South America, volcanoes are scattered among the high peaks of the big mountain chain which forms, as it were, the backbone of the American Continent.

Some of these are slightly active at all times, and occasionally there is a great eruption, as for instance Mount Katmai, Alaska, in June, 1912. So tremendous was that eruption that the sun was obscured full 20 per cent of his brightness, during July and August, 1912, over the whole Northern Hemisphere by the volcanic dust thrown miles high and carried around the world by the winds. Only two weeks elapsed between the explosion and the first appearance of its effects as far away as Algeria in north Africa.

Readers will recall to mind not only the San Francisco earthquake, but the numerous reports of earth tremors frequently occuring in the South American west coast countries. Chile especially has felt very severe earthquakes. A notable one in November, 1922, apparently took place just outside the coast line under the ocean, and its tremendous waves caused great losses of property and life additional to those caused by earth tremors themselves at several Chilean coast cities.

In view of all this, a committee was formed in cooperation between many scientific organizations of the United States and elsewhere to take up this pressing and interesting problem offered by the west coast. Dr. A. L. Day, director of the geophysical labratory of the Carnegie Institution, of Washington, is chairman. Among the exact measurements needed to base studies upon, it seems very desirable to sound the ocean off the California coast so as to be able in future to detect slips under sea as well as on land. How fortunate that just at this time the new method had been perfected by the Navy!

Under the direction of the Hydrographic Office, the Navy equipped two destroyers, the *Hull* and the *Corry*, with the sounding apparatus developed by Doctor Hayes. The actual soundings began on November 17, 1922, but the *Corry* required certain improvements of equipment so that the *Hull* continued alone for the first week, sounding the area between the Farallon Islands off San Francisco and Monterey Bay. Then both vessels proceeded to Point Descanso, Mexico, and beginning work November 28 sounded steadily northward till the work was completed December 21, 1922.

The two vessels had gone over an area of 34,000 square miles between Point Descanso and San Francisco Bay, measuring depths 5, or at most 10, miles apart over the whole range of depth from 100 to 2,000 fathoms. They had cruised over 5,800 miles in 38 days of sounding. Most of the work was done while moving at 12 knots per hour. Had this program been attempted with the old methods it might well have occupied the better part of a year.

TWO DECADES OF GENETIC PROGRESS.[1]

By E. M. East,
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Genetics was born 21 years ago when there came the first real appreciation of the studies on heredity made in the little garden at Brunn. Now that it has reached full manhood and is ready to assume the *toga virilis*, the time seems fitting to call back the yesterdays, to cast up accounts, and to judge whether the performance of maturity promises to repay the cost of infancy and childhood.

Perhaps it will serve our purpose to contrast the status of affairs toward the close of the long prenatal period previous to the twentieth century with that of to-day. When one does this, he is convinced that our chance metaphor is really rather apt. When the chick breaks through the egg, when the butterfly bursts the chrysalis, when the rosebud opens, the change is superficially so revolutionary that one is likely to forget the intensive energy expended in preparation for the natal day. So also with the study of heredity. Genetics was born and christened because of Gregor Mendel. Not because he diligently gathered facts regarding the heredity of the garden pea; rather because he was able to analyze and correlate these facts. Others had gathered facts galore. Indeed the growth-curve of knowledge had been rising steadily for many years. Yet metamorphosis came only when mathematics began to be applied effectively to the efforts of physiologist and morphologist. Change in method rather than a single great discovery gave the first real insight into the master riddle of the ages.

EARLY STUDIES OF HEREDITY.

Previous to the beginning of the twentieth century, isolated observations on heredity had been made by many types of workers. It was only natural that this should be the case. Such a seemingly mysterious force could hardly have failed to fascinate mankind from the very beginning of his speculative history. But isolated observations on subjects wherein are numerous complex variables usually

[1] Reprinted by permission, with change of title, from Journal of Heredity, May, 1922.

wait long for the keystone with which the generalizing mind can support an edifice of useful theory. And in this particular instance the time was undoubtedly extended by a striking aloofness and lack of a spirit of cooperation among the laborers in the various guilds.

The first tier of foundation stones was laid by the breeder. As was to have been expected, the empiricism of a practical art led the judicial classification and the inductive reasoning of science. One has only to study the wonderful domestic animals in the paintings and reliefs of Babylonia, of Assyria, of Egypt, to realize that knowledge of the effects of selection has been extant for at least 6,000 years, perhaps for 10,000 or 20,000 years. And Jacob's little scheme to mulct his father-in-law of the ring-straked and spotted cattle shows us somewhat of the older theoretical beliefs. Jacob, in fact, seems to have been as advanced a geneticist as many of the animal breeders of the nineteenth century, since the textbooks of this period express a similar belief in maternal impressions and other fables and contain not a single conclusion that one can now point out as having a permanent value.

Generally speaking, the history of plant breeding gives a little more cause for pride. True, the early Semitic knowledge of plant sexuality was actually lost until the latter part of the seventeenth century; but having rediscovered this fundamental truth through the work of Camerarius, the eighteenth and nineteenth century hybridizers did leave behind them several legacies well worth while. Kölreuter established the fact that reciprocal crosses give very similar results. A little later the efforts of such men as Sageret, Wiegmann, Gärtner, and Naudin placed three other conclusions on a firm foundation of experiment—the variability of hybrids of the second generation when compared with that of the first, the dominance of certain individual characteristics, and the occasional reappearance of the qualities lost to sight. Possibly analogous observations had been made previously by animal breeders; but it is certainly within the truth to say that even at the beginning of the twentieth century these were not accepted with anything like the unanimity which existed in the botanical field.

CONTRIBUTIONS OF MORPHOLOGY.

Morphology, with a much later start, got down to essentials a great deal more quickly than experimental breeding. Indeed, morphologists built so rapidly during the Victorian era they nearly reached a pinnacle of success that would have given us a different day to celebrate. They lacked but the inspiration to put their "ifs" to the test of calm experiment.

Logically it followed from the theory of genetic continuity by cell division that a material substance passed from cell to cell is the basis of all heredity. Naturally, then, the mechanics of cell division was the subject of intense investigation. The result was the discovery that in building up the tissues of the individual organism, in the preparation of the reproductive cells for their special work, and in the behavior of these cells in carrying out that work there was an essential similarity of the two processes in both animals and plants.

As these studies progressed it became apparent that the cell nucleus was the controlling agent of inheritance, and that within the nucleus the chromosomes played the star rôle. This hypothesis, put forth as a speculation by Haeckel in 1866, within 15 years gained the support of such eminent investigators as Hertwig, Strasburger, and Van Beneden, largely because of the similar elaborate preparations within the nucleus of egg and of sperm during maturation and of their apparently identical contribution of nuclear material in biparental inheritance. Numerous investigations on artificial fertilization were made by adherents and opponents of this view; but owing to the experimental difficulties involved, they were not conclusive. Polemic dissertations on the part played by nucleus and cytoplasm followed that were reminiscent of discussions in the realm of religion or of politics. Gradually the proponents of the view gained more and more converts, not because they were able to demonstrate a monopoly of directive action by the nucleus in development and heredity, not because they could prove that the intricate organization of so many unfertilized eggs was controlled by nuclear behavior, for such was not the case; it came through small increments to cytological knowledge which gradually wove a mesh so fine that there was no loophole of escape from the conclusion. Belief in the importance of the chromosomes grew, as in the case of organic evolution, not because of direct proof, but because of circumstantial evidence. Without going into an extended argument on the subject, one may recall the constancy of chromosome number in each species, their individuality in size and shape, the exactitude of their division during growth, and their peculiar behavior at the maturation of the germ cells.

NINETEENTH CENTURY THEORIES OF HEREDITY.

These facts, together with numerous minor discoveries, were the basis of nineteenth century theories of heredity. But besides the efforts of the practical breeders and of the morphologists, a serious attempt was made by Francis Galton and Karl Pearson to put genetic studies on a firm groundwork of quantitative experiment. Essentially their method was to measure the degree of association

between parents and offspring for any particular character. It was wholly a group method, and by its very nature precluded both the analysis of individual cases and the utilization of biological facts among the premises. Its chief generalization, the law of ancestral heredity, wherein the correlation of characters among blood relatives was interpreted as showing the inheritance of an individual to be made up of a series of contributions, one-half from the parents, one-fourth from the grandparents, and so on, has been shown to be erroneous. Having proved no stimulant to productive investigation, its discussion has passed from the genetic literature of to-day; but the mathematical procedure evolved by the Galtonian school has proved to be extremely helpful.

The earlier genetic theories of the period under consideration necessarily were highly speculative because of the paucity of known facts; but the fundamental postulate of each, active ultramicroscopic living units, has been retained in the genetic theory of to-day.

Darwin's provisional hypothesis of pangenesis (1868), for example, assumed that such particles, the gemmules, were given off at all times by every cell, and passed to all parts of the body including the germ cells. He thus accounted vaguely for the inheritance of acquired characters and for regeneration of parts, as well as for ordinary heredity.

Among several contemporary modifications of this type of theory was that of De Vries (1889), who assumed that the corpuscles, which he called pangens, represented potential elementary body characters rather than cell qualities, and that the universe of their activity was the cell rather than the body.

It is clear, even with only a glimpse of such theories, that they could satisfy none but the philosophically inclined. They did little or nothing toward stimulating work designed to test the points involved.

A different fate met the speculations of Nägeli (1884). Here was postulated two types of protoplasm built up of physiological units, the micellæ: The one was nutritive in its functions, and required no particular architecture; the other, the idioplasm, a structure of elaborate constitution, was built of units which represented the potential elementary characters of the organism.

WEISMANN'S THEORY.

Utilizing this conception, Weismann (1892) evolved a theory which more nearly fulfilled the requirements of an experimental working hypothesis than any of those previously outlined. The

idioplasm or germplasm he identified with the chromatin of the nucleus. His ultimate physiological unit, the biophore, was the biological atom active in building up organic characters. Grouped together into higher units, the determinants, these corpuscles controlled the specialization of cells. The various determinants of an organism made up the *ids* contributed by past generations. The *ids*, if more than one, might differ slightly among themselves, thus governing variation within the species. They formed the chromosomes, or *idants*, by arrangement in a linear series.

Denying the inheritance of acquired characters, and doing much toward demolishing the fallacious logic put forth as proof at that time by adherents in the belief, Weismann outlined a very stimulating conception of heredity on this basis. The immortal germplasm was assumed to be set apart at a very early cell division and passed along unchanged to the next generation, except as the activities of the living units produced occasional changes in its constitution. A provision for accurate equational division of the chromosomes and their reduction in number at the maturation of the germ cells was thus demanded, predicted and afterwards realized—though not precisely in the way he supposed—by discoveries in the field of cytology.

Weismann further accounted for evolution by a selective struggle between the determinants of the germ cells, and for individual development by a qualitative distribution of the determinants of those cells set apart to build up the bodies which were to act as hostelries for the immortal germplasm.

With Weismann is reached the peak of genetic generalization at the beginning of the twentieth century. To-day we have parted company with him in many particulars, nevertheless if modern genetic theory can be said to be the outgrowth of any earlier school, the Weismannian school must be given the preference. As Wilson has said, he brought "the cell theory and the evolution theory into organic connection." His work, besides dispelling many old wives' notions by its cutting logic, was second only to that of Mendel in making genetics an experimental science. Morgan credits him with "the basis of our present attempt to explain heredity in terms of the cell" in that he propounded three of the principles upon which the modern Chromosome Theory is founded.

WEISMANN AND MENDEL.

Some may see an inconsistency in ascribing the ground-work of current ideas of heredity to Weismann, and yet celebrating the rediscovery of Mendel's papers as the true break between the old

and the new. The obvious reply would be that it takes more than three foundation stones to prop up a useful structure, and that Mendel furnished several examples, most beautifuly cut and polished. But there is a deeper truth than this to be emphasized. Weismann unquestionably had a breadth of mental vision far exceeding that of Mendel. He was a real clairvoyant of science, too, and not a mere visionary in the cynical modern sense of the word. Nor was he above the drudgery of experiment. But he failed to have the good luck of initiating a simple method whereby the elementary quantitative relationship between hereditary phenomena could be tested and retested by those who followed him. This fortune fell to Mendel, who, though in a comparative sense a narrow man, was yet able to grasp somewhat of the significance of the results obtained, and leave an imperishable monument to his name. No one may say he was the greater man, but no one can deny he left the more useful work. His results are a satisfaction to the rank and file of scientists for just this reason. They leave a ray of hope to the plodders with whom most of us trail.

The path opened up by Mendel has joined with the path cleared by morphology to produce a road that has extended some distance during the past two decades; but to point out the cairns and avoid falling into the pits is not an easy task. The road makers have been numerous, and in general, honestly constructive; but in order to hold this article within reasonable limits I shall mention few names except to pay a just tribute to Morgan as the master craftsman. Nor shall I speak of the attempts at sabotage except to say they have become more and more infrequent. I shall merely endeavor to recapitulate the fundamental points as best I may with the hope that the effort will not be far afield. At the risk of becoming wearisome I want to try to estimate the progress in terms of general conclusions rather than to describe a heterogeneous selection of ancient heredity puzzles that have yielded to simple interpretations.

GENETICS AND EVOLUTION.

First, it must be emphasized that though modern genetics has brought about a clearer orientation of the problems of development and of evolution, it has been concerned directly with the mechanism of heredity. Least progress has been made in connection with the problems of ontogeny. But the conception of where the one ends and the other begins, in so far as this is possible, has become much more definite—at least in this country. It is probable that the interesting phenomena recently described by Mr. Bateson where

seeds from various parts of the same plant apparently transmit different characters, would be less likely to appear so puzzling if this were clearly recognized. And even if we admit our inability at present to contribute much toward the solution of the question, so well delimited by Weismann, of somatic specialization during the development of the individual, one can not but feel that further progress in dealing with problems of straight heredity will ultimately be helpful.

As to the grand problem of evolution, I believe there has been a concrete offering. True, the question of "how" is still in *statu quo;* but one must be rather a pessimist if he does not consider that the current conception of the gene presents something tangible on the subject. It certainly allows a definite distinction between variations due to environmental fluctuations, variations due to rearrangements and combinations of genes, and variations due to change in the constitution of the unit of heredity itself. Furthermore the data now being gathered on the type of gene changes occurring, and on the frequency with which they take place, are not to be cast aside as of no value to the evolutionist. A statement as to just what they mean would be a daring assertion, but that they mean something now and will mean more later can not be doubted.

Let us take, for example, the following illustrations, which, I think, are fair.

1. Mutations (gene variations) are now occurring in all species that have been investigated intensively.

2. There is a wide range to mutation frequency in different species.

3. The number of useless or of harmful mutations is *many times the number of useful or of beneficent mutations.*

4. The number of mutations affecting chiefly certain organs or particular tissues greatly exceeds those affecting other parts of the individual.

5. The "conservative" parts as measured by mutation frequency, appear to have slight relation to the "conservative" parts as determined by the circumstantial evidence of the phylogenist. For example, loss of the ligule, a characteristic of the grass family, has been found in a goodly number of the cultivated grasses—these being the only ones that have been studied very carefully.

6. Mutations are often reversible. Reversibility may not be universal, though the mere fact that it has not been observed in every case proves only that the reaction does not take place in both directions with the same ease.

7. Mutations which from their major effects can be arranged in a graded series—for example, eye color of *Drosophila melanogaster*—are found not to have originated in that order. That is to say, such

orthogenetic phenomena as have been observed are better interpreted as analogous to chemical phenomena, where tendency to certain reactions is greater than to others, than as "vital force" phenomena.

No one can maintain that these genetic findings compare with the fundamental laws of thermodynamics in elegance and simplicity. No one can say how general they are. But fruit flies and maize, rodents and peas, upon which the observations were largely made, are pretty far apart in the general scheme of things; therefore it would be very odd indeed if they should turn out to be special cases. And to me they are very helpful to a clearer general conception of evolution.

THE MECHANISM OF HEREDITY.

Turning now to the mechanism of heredity, let us see what can be said. The main generalization is that there are units of inheritance, the genes, which are constant in the sense that stable chemical compounds are constant; and whose distribution follows the distribution of the chromosomes. In other words, the discoveries of experimental genetics have made it possible to endow the conceptual units of earlier days with particular qualities, just as discoveries in the physical sciences have made it possible to delimit the characteristics of atoms and molecules. Presumably there may be other types of inheritance, but the only one thus far described is an exclusively maternal inheritance of certain plastid characters. And even in this case, it is not absolutely certain we are not dealing with symbiotic organisms that are transferred from host to host in some such way as the numerous more or less yeast-like forms being daily described in relation to insects and other lower animals. The mere fact that numerous dicotyledons and monocotyledons on the one hand, and mammals, birds, amphibians, reptiles, fishes, arthropods, and molluscs on the other, show essentially identical types of heredity, makes it probable that the generalized mechanism has been discovered. At the same time, though the angiosperms, insects, and mammals thus far studied intensively, distribute their units of heredity with a convincing similarity of detail, it is altogether likely that special cases of peculiar distributions will be found later. And there is every reason to believe that these odd or unique types of inheritance will parallel a specialization in chromosome distribution departing somewhat from the one we have come to look upon as regular.

THE LAWS OF HEREDITY.

This regular or common scheme of chromosome distribution in sexual reproduction has been the basis of practically all of our present genetic knowledge. From past experience with it one can pick out the following inductions, each of which has been tested with

variable degrees of thoroughness. They are not set down here with the idea they are necessarily more inviolable than the laws of the Medes and Persians, but merely with the annotation that no experimental data have thus far overstepped them except those on the plastids. They may be called provisional laws of heredity.

The first five of these generalizations describe the mechanism of heredity in the preparation of the germ cells for fertilization.

1. *There is segregation of paternal genes from maternal genes, each unchanged by the association.* The pedigree culture evidence supplements the cytological evidence in favor of the idea that this segregation takes place at the reduction division of the chromosomes in the maturation of the germ cells, when homologous paternal and maternal genes pair and separate, one of each pair passing to each of the two daughter cells.

2. *There may be any combination of the choice of one out of each pair of genes in making up the genetic constitution of the gametes.*

3. *In transmission to the two daughter cells, certain sets of genes are always manipulated independently of all other genes.* This is a statement of independent inheritance, or rather of independent genetic recombination, without reference to the chromosomes. It is an unworthy piece of quibbling, however, not to accept the simple indication of cytology that this law is the result of the operation of the chromosomes acting as gene carriers. It results from the fact that No. 1 pair of chromosomes, no matter how it may be packed with genes, carts its cargo independently of all other pairs.

4. *The manipulation of genes within a given series is always dependent.* This is the phenomenon of linkage, or association in inheritance. Concretely, we assume that the genes packed within each freight carrier pair, an homologous pair of chromosomes, are mutually dependent to various degrees in their recombinations with each other.

5. *The number of dependent series or linkage groups is limited.* In the fruit fly, the number corresponds to the number of chromosomes, and the presumption is that this is the case in every species.

Added to these five laws are four more generalizations which refer particularly to the architecture of the germ plasm within the carrier.

6. *There is a stable orderly arrangement of genes.*

7. *This arrangement is linear.* The genes appear to be strung together much as a string of magnetized steel balls.

8. *Rearrangement of genes after linkage breaks is stable, orderly, and linear.* By this it is meant to say that rearrangement of the package after interchange of the contents of a pair of carriers is also constant and of the same linear order as in No. 6 and No. 7.

9. *A regularity of behavior has been found in the interference of one crossover or linkage break, with a second crossover in the same carrier, which says that the per cent of crossovers varies independently of the per cent of interference.* The converse is also true.

There is a facination to this picture of germplasm architecture, and the type of investigation which has led to these statements will undoubtedly lead to still greater things in the future; but we should do well to realize that each of these generalizations, except probably the sixth, may be a special case; and that new and different special cases may be found without necessitating a change in the first five conclusions.

There is just one other generalization to be mentioned. It is the only one concerned with fertilization, and upon its truth has largely depended the discovery of all the others.

10. *There is no selective fertilization between complementary, compatible, functional gametes.*

In other words, if a series of male gametes meets a series of female gametes sufficiently alike to be compatible with them, fertilization takes place by chance. Clearly chaos would result if this were not so. Gametes produced by a single hermaphroditic organism may present hundreds of hereditary differences. The slightest tendency to selective fertilization, therefore, would prevent genetic analysis of the results. Happily, this is not the case. Even in the flowering plants where varying lengths of pistil tissue must be traversed by the male gametophyte before fertilization is possible, evidence has been offered that rapidity of passage probably is not affected by differences in gametic constitution. Genes evidently do not begin to function as such until the life cycle of the new generation commences.[1]

OTHER FACTS OF HEREDITY.

There are other categories of facts, several of them probably not flowing out of the above conclusions, that are as interesting to the general biologist as the abstract laws. Without them one can not get a just idea of the actual concrete working out of the heredity mechanism.

First let us speak of dominance. Dominance was originally defined as an observational phenomenon, the appearance of the effect of one of a pair of different homologous genes, as opposed to the disappearance or exclusion of the effect of the other. Later, it was taken to be the presence of an effect as the antithesis of its absence; and this idea was carried to such lengths that many geneticists came

[1] It should be mentioned, however, that in Nicotiana (several species) and in Zea the pollen tubes from different plants exhibit different rates of growth under similar conditions. The rates appear to be controlled by the genetic constitutions of the mother plants from which they came.

to believe that dominance of "A" over "a" was due to actual absence of any function of "a," or even to the physical absence of any gene whatsoever. Now we have come to see that dominance is a mere arbitrary measurement of the approach of the result "Aa" to that of "AA" or "aa." This has been brought about by finding cases in which the effect "A" or "a" in the haploid condition could be compared with the effects of "AA," or "Aa" and of "aa." These cases make it seem doubtful whether the association of "A" with "a" ever wholly inactivates the latter.

With this conception of the function of the genes in mind it is possible to work out pretty definitely the actual resultant ontogenetic characters after different matings, both with and without linkage, by applying the laws I have just discussed. It is merely a straight mathematical relationship following immediately after acceptance of these basic conclusions. But there are several difficulties involved in identifying the concrete results of breeding with the abstract results of calculation. Some of these difficulties have been leveled, others are yet to be overcome.

One must realize that each gene has many effects on the organism, some of which are not easily discoverable. The fact that a gene is usually ticketed with a name indicative of its most obvious effect on a particular character, should not mislead us in this regard. Then, too, one must remember that many genes affect each organic character; and that similar characters, characters apparently identical, do not necessarily owe their qualities to the same combination of genes. And, finally, it does not follow from any of the above relations, what will be the result of gene interaction. The action of two or more genes may be necessary to bring about a visible or measurable result, though these genes may be carried along separately generation after generation. The full logic of this fact tears down the veil from many an obscure result; since the difficulty of appreciating the results of selection has been due to the failure to realize how many modifying genes may be carried along which have no chance to produce a measurable effect unless a certain basic gene complex necessary for particular organic expression is also present.

This short sketch will show, I hope, that in the 21 years of experimental genetics real progress has been made. To be sure, this résumé has been a leaping from crag to crag. No more was possible within the editorial limits here allotted. But if one recalls the scorn of 50 years ago should a daring seer have predicted such a triumph for quantitative mechanical analysis in a subject so overstrewn with variable factors, he in turn will scorn the Freudian overcompensation of to-day's critic who makes the taunt that it shall go no further.

OBSERVATIONS ON A MONTANA BEAVER CANAL.[1]

By S. Stillman Berry.

[With 6 plates.]

Less frequently seen than the spectacular dam and lodge, but, when in a state of perfection, well nigh exceeding either in the interest and wonder which it invariably arouses in the mind of one fortunate enough to encounter it, is the unique example of beaver engineering known as the canal. As familiarity with it increases, one rarely fails eventually to regard it as altogether the most astounding evidence afforded us of the beaver's extraordinary "capacity," as Willey puts it, "for suiting its labors to the nature of the district which it inhabits."[2] The attempt to explain it on the basis of hereditary instinct alone, in the narrow sense of the word, is not wholly convincing. The comparative rarity of the canals, at least in their more developed forms, only adds to the astonishment with which each new observer views so purposeful a conquest, through efforts both individual and cooperative, of difficulties which must, from the very nature of the case, be almost wholly peculiar, local, and therefore *original*. Not only is there nothing stereotyped about the construction of the canal, but given the closest possible parallelism in attendant circumstances, the answer to even the flat question of whether a canal will be built or not is variable. In many regions where beavers are known to flourish, their haunts may be explored to the end of time without finding so much as a trace of an attempt at canal building,[3] while elsewhere a colony situated under what would seem far less favorable conditions has laboriously constructed entire systems of these waterworks. Nor must the possibility be overlooked that different species or subspecies of beaver may not be possessed of the same natural capacities in this direction.

[1] Reprinted by permission, with minor changes and additions, from Journal of Mammalogy, vol. 4, No. 2, May, 1923.

[2] Yet Lydekker, in the article "Beaver," in the eleventh edition of the Encyclopædia Britannica, fails even to mention the existence of the canals.

[3] It must be admitted that lodges, too, are in some places conspicuous only for their absence, while some colonies have so forsaken more usual habits as, temporarily at least, to have given up even dam building.

The entire phenomenon of canal building by beavers is surely worthy of a far more intensive study by observers trained in modern methods of the investigation of animal behavior than has yet been given it. When such sporadic observations as the few which have been made include so much of more than ordinary interest, a genuinely exhaustive investigation could hardly fail being fruitful. It is because prior to so desirable a consummation even relatively minor contributions may prove of interest that these notes have been published. At least one basal fact seems to be pretty thoroughly established: These artificial waterways are constructed primarily for the transportation of food, thus bearing an analogy to the more pretentious canals of human construction, and, like the latter, they appear to be only secondarily utilized for the transportation of building materials, for the diversion of needed or superfluous water, or as simple thoroughfares for the beavers themselves. I would not deny that there are sometimes individual canals which situation or other circumstances quite conclusively indicate to have been intended largely or wholly for one or the other ordinarily subsidary purposes last mentioned. Indeed several such examples have been cited by Mills,[4] in a volume which contains quite the best account of this phase of beaver activity that I have been fortunate enough to encounter. But this does not gainsay that the primal urge back of all this cerebral activity, whether or not any degree of intelligent control of the instinct be admitted, is that of food getting.

The aspen, or quaking asp (*Populus tremuloides* Michx.), is said to be the tree the bark of which is most keenly sought by the beaver as food, but in the absence of the aspen various other species of the Salicaceæ, notably certain of the cottonwoods and willows, with perhaps one or two other trees, seem to serve just as well. However that may be, once the supply immediately adjacent to the winter feeding basin has become depleted, the simplest recourse (for the beaver) is to push his foray farther afield, and, as even his most faithful admirers admit him to be far more agile and dexterous in water than so heavy and nearsighted a creature can ever be on land, what more natural when he wishes to take advantage of a slightly more distant forage plot than that he attempt to carry his medium thither with him! Instinctive or intelligent, such resourcefulness must often be of survival value to the animal.

For the past five years the writer has had under intermittent observation a very long and in some ways unusually highly developed beaver canal which is the subject of the following account. It is

[4] Enos A. Mills, In Beaver World, pp. 77, 103, 106–107, 145, 149 (1913).

situated on the Winnecook Ranch, one of the old-time stock ranches still persisting a few miles east of Harlowton, Mont. Therefore some degree of protection of both the canal and its architects has been possible during a part, if unfortunately not the entirety, of the period of observation. More generally the location may be stated as Wheatland County, south-central Montana, whereof the principal body of water is the Musselshell River, a considerable stream traversing the entire county in a west to east direction, and inhabited, at any rate in favored stretches, by colonies of beaver.[5] The more striking physiographic features of the river and its immediate environs are fairly constant throughout this area. The prevailing bench lands of the north, and the rougher and more broken hills to the south, as in all our upper prairie country, terrace down to a sharply defined, narrow, and comparatively level "bottom," through which meanders, though frequently with considerable current, the river itself on its way to join the muddy torrent of the great Missouri. The only "forest" is an irregular, yet generally abundant growth of cottonwood trees (*Populus*, spp.), in their primeval state all intertangled with a thick undergrowth, "the brush," composed of such smaller trees and shrubs as willows of divers species, buffalo berry (*Lepargyrea argentea* Nutt.), chokecherry, dogwood (*Cornus stolonifera* Michx.), wild roses, currants, gooseberries, and other associated types, which borders the actual stream channel, forming a continuous belt of an eighth to a half mile in width, but giving way here and there to more open parklike spaces, or long swales or sloughs. In spite of the encroachments of civilization and a relentless persecution at the hands of farmers and less legitimate foes, which have combined in so many regions to force the beaver to surrender all his more characteristic and conspicuous ways of life or be exterminated, in many a serene nook along the Musselshell his lodges, dams, trails, slides, food piles, abandoned stumpage—indeed, his own picturesque self, are still to be observed in something like their original perfection. And since this particular race of beaver seems to be especially addicted to building canals, these are by no means lacking.

The particular waterway in question (pl. 1.) is by all odds the finest specimen of this type of work which has been discovered in this neighborhood. Just above the point where the canal becomes tributary to the river, the Musselshell is quite deep in places, even at the lowest water. Slides, tracks, peeled twigs, food piles, and other evidences of beaver occupation have long been numerous there and I have little doubt but that somewhere hereabout is the principal

[5] I am not aware that the specific determination of the beavers inhabiting the Musselshell and its tributaries has ever been made. The present locality seems to be rather close to the supposed boundary between the ranges of *Castor canadensis* and *C. frondator*.

home, or at least the site of the parent colony, of the beavers who built the canal.

The river wanders much through this part of its course, and in the not distant past has veered and shifted and migrated so that the cottonwood forest springing up along its successive beds has produced an unusually broad piece of woodland at this point, especially to the south of the present course of the river, and there are many of the little open parks, twisting lines of trees marking former channels, shallow depressions, and narrow swales bordered by willow thickets. Straight back into this native tangle the beavers have found occasion to build their canal. Although one of the best traveled ranch roads of the time led through a large park immediately west of the canal, while not a great way to the east was a much-used sheep shed, so swiftly and unobtrusively did the beavers carry out their work when once engaged upon it that in the spring of 1916, when one of the ranch boys happened to stumble into it, the canal had been completed, we know not for how long previously, and was being abundantly utilized. There are two reasons for believing that at this time the canal of a fact had not been in existence so very long. In the first place, when discovered it was at the very acme of structural perfection, indeed was so finished in detail and so well kept that some of those who first saw it, who happened to be ignorant of beaver structures, had no thought of it as possibly of other than human origin, and expressed a wonder as to who could be running so well constructed an irrigation ditch through that particular piece of forsaken jungle, and more especially how it could have been constructed without their knowing it—an amusing statement to make, but not surprising considering the original symmetry of the canal. In the second place, when the present writer first visited the canal, on the succeeding 29th of July to be exact, the principal tree fellings adjacent to the middle and upper reaches of the canal were in the main quite fresh. Many fellings were in progress at the time and similar work continued all through that summer. The canal was revisited a number of times that season and likewise during the summer following by the writer and others, but it was not until August 25, 1918, that it was thoroughly explored, its real extent appreciated, and the entire system as carefully measured and plotted as was feasible in the absence of a surveying equipment. Most of the notes forming the principal basis of the present account likewise date from that time.

The general trend of the canal, together with its succession of contributory works, is practically south to north. Principally as a direct result of disturbing variations in the character of the terrain which

it traverses, the system is composed of several very differently constructed segments. Since so far as the watercourse proper is concerned these segments chanced to coincide almost exactly in extent with the three principal curves, it becomes convenient to resort to a correspondingly arranged treatment for its description. A glance at the accompanying diagram now and then will be helpful in rendering this point and much of the remainder of the discussion clearer.

The first or lower segment (pls. 1 and 2, and pl. 3, fig. 1) comprises, or rather did comprise, the main canal, leading in the form of a crescent from the river into a long slough curved in the reverse direction, which was utilized as the second segment of the canal and only here and there exhibits evidence of artificial treatment by the beavers. The third segment is made up of a much narrower canal which passes by way of an ephemeral rivulet into a mere beaten trail which finally loses itself in the undergrowth, some 1,145 feet measured by the canal, from where the latter left the river.

The first-mentioned division of these extensive works, therefore, is readily seen to be the one of primary importance and interest. The terrain here not only offered certain special advantages for the construction of such a work, but at the same time certain noteworthy difficulties, all of which seem to have been taken advantage of or overcome, as the case chanced to be, in quite a remarkable manner. A little way back from the river and separated therefrom by a low, willow-covered ridge is a narrow swamp, no doubt originally a prolongation of the large slough mentioned in the last paragraph as constituting the second principal segment of the watercourse. Students of beaver bionomics have more than once called attention to the interesting aptitude exhibited by the animals in carrying a canal across a slope by banking the excavated earth largely or wholly on the down side.[6] In the present instance a complication enters in, the mastering of which has resulted in perhaps the most interesting single claim to novelty which this particular canal possesses. For in order to bring about the desired connection between the flooded slough and the river the beavers had not only to pierce the low, willow-clad ridge near the river (pl. 4, fig. 1), but in some way to carry their watercourse across the depression occupied by the miry swale. By felling and removing innumerable willows they might have accomplished this in the usual manner followed in crossing a simple slope, running the canal along the bank of the swale and banking it on the down side only, but this would have necessitated an enormous amount of labor. There was a better way to solve the problem, a way which any irrigation engineer would have chosen under the pressure of similar circumstances, and this was chosen

[6] E. g., Mills, In Beaver World, p. 88.

by the beavers. They plowed their channel right through the center of the swale and *banked both sides* of the canal (pl. 2, fig. 1). In 1916, when the work was new, the *levees* so constructed were very conspicuous, and sufficiently high to enable the beavers to fill the canal to a level appreciably higher than that of much of the immediately adjacent terrain. In winter these levees gave rise to an especially curious effect at times, for when the snow receded they were exposed first and showed as two narrow parallel ridges protruding through the white mantle covering the canal and the surface of the swale (pl. 2, fig. 2). Beginning exactly at the lower end of the flooded slough, though a little to the northeast of the center thereof, the levees featured the canal for a distance of some 215 feet. In fact, this entire lower portion of the canal was very regular and as exact in construction as rather careful human hands would likely have made it. An entertaining incident occurred in 1916, the year the works first came under observation, when one of the ranch hands chanced to place a large board across the canal to serve as a bridge in passing over it. The beavers failed to appreciate this obstruction to their traffic and at once got about its removal. Whether one, or more than one, animal was so engaged we did not discover, but in any case the board was set upon from both sides without much evident coordination of effort. Two good-sized crescents were thus bitten away, but not being coincidently directed the obard was still holding pretty well when I last saw it (pl. 6, fig. 1). This is hardly to be adduced as proof of very keen intelligence on the part of the beaver, but it must be admitted that man himself would obtain a poor verdict were he similarly judged on some of his own incidental behavior.

Although I speak of the canal as opening *into* the river, I never was able to determine which end was actually the head and which the foot of the main portion. When I first saw it in July, 1916, all the water was out of it except a mere trickle which drained into the river. There were plenty of fresh beaver tracks in the muddy bottom and those of white-tail deer, coyotes, wild cats, and a few smaller animals along the levees. In 1918 it was full, or nearly full, of water, which was slowly flowing *away* from the river and into the slough. That same summer a little later I saw the water in the canal so nearly neutral between river and slough that floating particles moved now one way, now the other, in the most indeterminate fashion. Sometimes the water was noted to be flowing steadily toward the river. The obvious explanation of this curious state of affairs would seem to be that this part of the canal was so nearly level that the direction of whatever current manifested itself depended wholly upon the relative levels of the water

in river and slough. But in practice the problem failed to resolve itself so simply, and I have sometimes been quite at a loss to explain a given reversal in the direction of flow. With the river at fair flood I have found the entire beaver works nearly empty, while the last time I saw the canal with any head of water it was setting distinctly in the direction of the slough although it was the last of August and the Musselshell was in its season of low ebb. It is possible that the condition of the big slough is a more important consideration for the behavior of the water in the lower canal than that of the river. When the Musselshell is very low the river end of the canal is necessarily high and dry, and at such a season the slough also is apt to be reduced to a mere quagmire. Measurements taken in the latter part of the month of August, 1918, showed that near the main bend (x—x in the accompanying diagram) the canal had a low-water diameter of 5 feet, or of 9 feet 6 inches measured across the summits of the levees at the same point. At the mouth it was 9 feet in diameter (8 feet at water level), with a maximum depth of 1 foot 8 inches and a low-water depth of 10 inches. Where it cut through the willow bank (y—y of diagram) the canal diameter at high-water level was 6 feet 9 inches; at low-water level 5 feet 6 inches. The low-water depth at this point was 1 foot to 1 foot 3 inches. The river near the mouth of the canal was about 50 feet wide at this time. At the date of these measurements the leveed part of the canal had already begun to deteriorate badly. The banks were partially worn down (pl. 1, and pl. 3, fig. 1) and the hollows in the swale largely filled in by the washings, but [illegible] places, especially on the lower or east side, the banks remained to some extent leveed above the adjoining ground. It would appear that in its pristine condition, upon emerging from the willow-clad ridge, the canal opened directly into the river very nearly at right angles with the shore line, or even deflected to head a trifle upstream. But a heavy mud bank was later silted across it by the river current so persistently that after a little effort to keep open an adequate passage across it, the beavers capitulated and sheared away the shore [illegible] east a little in such a way as to run their channel downstream back of the bar, across the foot of which it then opened obliquely into the river without much danger of further blocking (pl. 4, fig. 2). Up to this time there were no dams of the beavers' own making either at the river opening of the canal or at its juncture with the flooded slough, or, in fact, at any point between.

In 1918, and at certain times previously, the slough (pl. 3, fig. 2) at the head of the leveed canal was a turbid lake some 260 feet long and 40 feet across, bordered, like the swale at its foot, by a thick growth of

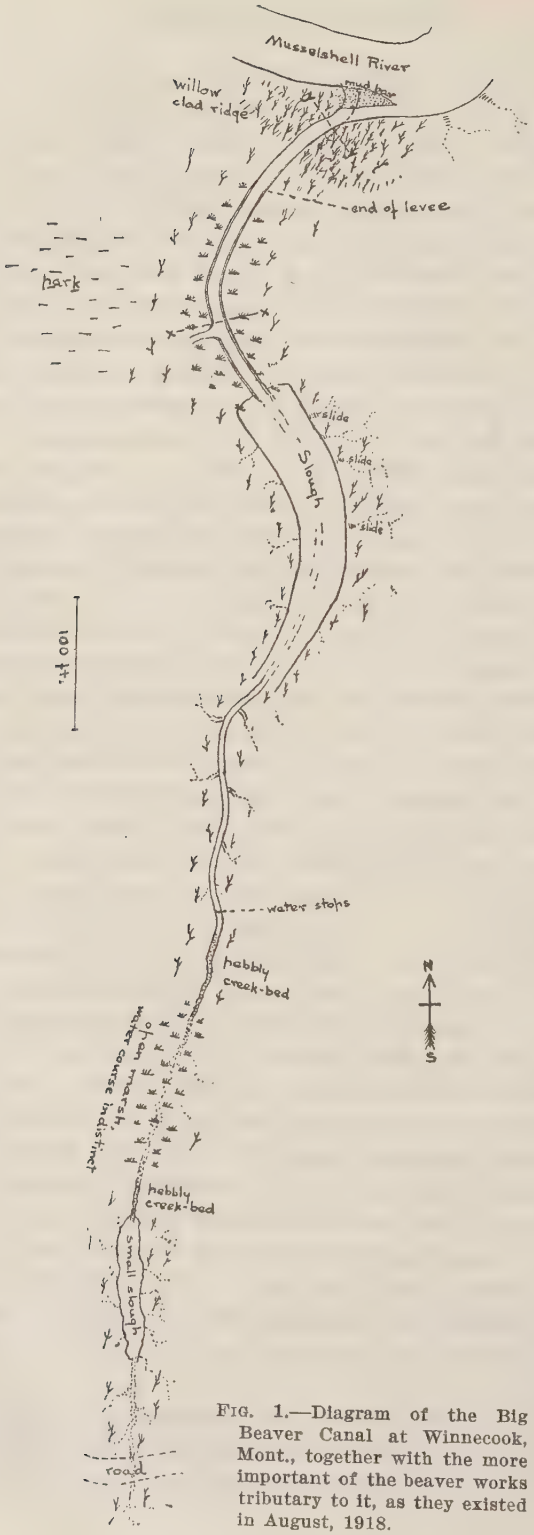


FIG. 1.—Diagram of the Big Beaver Canal at Winnecook, Mont., together with the more important of the beaver works tributary to it, as they existed in August, 1918.

scrub willows, wild roses, and a few dogwoods, with cottonwoods of two species rising farther back. Many of the willows and cottonwoods, particularly at the upper end of the slough, had been felled, numerous slides on the steep east bank and trails leading through the growth of willows to both east and west yielding abundant testimony of the activity and industry of the rodent woodsmen. There was also evidence of the floating of considerable quantities of felled timber via the slough into the canal and thence to the river. The attainment of this inland timber was of course the principal motive for the building of the canal, although the beavers seem to have made the flooded slough the domicile of a part of the colony at this time.

But a further quantity of very desirable willow and cottonwood growth still existed farther up between the slough and the hills. I had previously noticed beaver cuttings as far beyond the slough as the road crossing, on numberless occasions, but had never thought to associate them with the beavers of the canal, nor to explore the upper end of the slough, at any rate until August, 1918. At that time, in company with Mr. A. W. Bell, I traversed the entire length of the slough in order to measure it, and was quite unprepared to discover thereupon in the willow tangle at its head a continuing canal leading on to the south through the dense thicket. The ground here was marshy and many little side canals had been pushed off into the willows toward the firmer ground on either side. This canal was neither so ambitious in magnitude nor in any respect so finished in construction as the lower one. A narrow, pebbly creek bed of some former time, hardly more than a foot in width, underlay its upper reaches, uncovered where the beavers had pushed back the swampy mire which had engulfed it. The flooded part of the canal did not quite reach this point when I saw it, but there was evidence that at no very distant time the water course had extended considerably farther. Perhaps a hundred feet farther on even the pebbly creek bed became indistinct where it traversed an open marsh, but beyond this it emerged once more and the trail continued to follow it very plainly to an old beaver slough another hundred feet in length, with felled trees and other beaver signs all about. At this time all these relics were more or less weatherworn and very fresh indications of beaver activity were quite wanting. Above this last small slough, it was still possible to follow the main trail for perhaps yet another hundred feet. But here it constantly grew fainter and finally lost itself entirely about where the road crosses through the little break in the woods where the beaver cuttings had first been observed.

As there is evidence that the beavers themselves have at times been responsible for the flooding of the big slough, and they have actually excavated its bottom in places in line with or even in continuation of the upper and lower canals, it seems only just to reckon the entire length of the watercourse, or 745 feet, as that of the canal. So credited, it becomes one of the longest which has been recorded.[7]

In summary then it may be said that the canal seems to occupy, and in large degree to have taken advantage of a long swale, which at its upper end bears evidence of being the remnant of an ancient rivulet, now dry, the lower portion now at best not possessing gradient enough or running water enough to maintain an unbroken outflow into the river. This necessary detail was accomplished by the beavers, who have pushed their canal through a cut in the vegetation-covered bank of the river, and thus made possible the full development of the entire system.

The canal has now been under observation as opportunity has presented for six summers, and I have also been able to pay it a winter visit or two. As has been related, the canal was in its highest state of perfection in July and August of 1916. A year later it had been somewhat damaged by the abnormally high water of that season, and although it continued to be occupied it was never fully restored. In July of 1918 I found it very miry and in bad shape in other particulars, but the beavers were still actively utilizing it and did a little work on it during the rest of that summer. A miserably cruel and needless onslaught carried on against them by persons who chanced to be temporarily connected with the operations of the ranch along about this time so depleted their numbers that until quite recently it was feared it would be many years before the damage could be made good. Certainly the canal showed the effect of this slaughter, for in 1919, which was a year of almost unprecedented drought and low water, when they would normally have been exceedingly assiduous in storing back as great a proportion of the retreating waters as possible, the entire canal was absolutely dry, pond and all, and badly

[7] Seton (Life Histories of Northern Animals, vol. 1, p. 458) records a beaver canal at Gal Pond, in the Adirondacks, 654 feet long and some 4 feet wide, leading "from the pond to a grove of poplar and yellow birch." "Although abandoned for fully 50 years, it was very well marked and showed many beaver cuttings." Most of Seton's discussion of beaver canals is, however, taken from Morgan.

Mills (In Beaver World, p. 140–141) describes and illustrates a remarkable canal near Long's Peak, Colo., which was excavated through a deep wreckage of fire-killed and fallen spruces in order to permit the successful harvest of a certain grove of aspens. This canal was 334 feet long, with an average depth of 15 inches and a width of 26 inches. Still more noteworthy is the very complex canal which he observed near Three Forks, Mont. (op. cit., p. 107–111, fig.), and which had a total length of 428 feet.

By far the longest canal recorded by this author was observed at Lily Lake, Colo. (op. cit., p. 104, ill. opp. p. 102). This canal was one of a number built by the beavers of the local colony in order to maintain necessary water thoroughfares in the bed of their home lake during a time of drought. It was measured to be 750 feet long, 3 feet deep throughout, and from 3 to 5 feet wide.

grown to rushes and weeds. No evidence whatever of renewal of beaver activity anywhere along the canal was detected either that summer or the next. In fact by August of 1920 the unoccupied canal, still nearly dry, had been washed in at the sides all along the line, and the lower canal as well as even part of the former pond were almost completely smothered in the rank growth of rushes, sedges, arrow weed, marsh grass, and similar plants which had overgrown them.

Meanwhile there was put into effect on the part of the ranch management a more enlightened and forward-looking policy respecting the care of such wild creatures as still remained within the bounds of its jurisdiction. Hopeful that the beaver in particular would eventually respond to the more sympathetic treatment, I nevertheless was completely taken by surprise, upon revisiting the old canal in August, 1921, to find there already indubitable evidence of their resumption of domain. The pond had not been again flooded, nor did I notice any fresh beaver work near the road crossing or in visited portions of the intermediate area, but the lower segment of the canal showed a narrow median strip which had been dredged clear of weeds and basined out, and had evidently lately carried a flow of water, although for the time being it contained none (pl. 5, fig. 2). The extreme lower part of the canal adjacent to the river still retained approximately its original dimensions with the weeds only slightly encroaching at the sides. The mud bar still persisted, but strangely enough it had been cut through once more and the original opening of the canal approximately restored (pl. 5, fig. 1). But the halcyon days of the leveed portion were no more. The old high banks were merged in the surface of the swale, and the newly excavated tract in the middle had a bottom width of but 10 to 15 inches, a high water diameter of but 15 to 30 inches, and a maximum depth of not exceeding 4 to 5 inches. Even worse, across the canal, about 30 feet above the mud bar, had been thrown a massive dam of well-packed mud and sticks, so inordinately high in relation to the usual water line of the old canal as to suggest very forcibly that it could be intended not so much to keep the canal from draining out, as to keep the flood of the river (at high water) from pouring in. Just a little down river the steep bank on the same side of the canal showed several holes and fresh slides. It was greatly hoped that the construction of the dam did not signify a final desertion of the canal, but that the activity of this colony of beavers would soon be pushed to the accomplishment of perhaps yet more interesting results. In this I was disappointed, however, for upon a visit to the canal in September, 1922, we found its desertion apparently complete; this in spite of abundant beaver signs in the neighboring stretches of river.

The linear measurements of the canal and its contributory works as they existed in August, 1918, are summarized in the following table:

	Feet.	
Leveed portion of lower canal	215	
Gross length of lower canal	285	
Length of flooded slough	260	
Approximate length of upper canal	200	
Total length of water course		745
Approximate length of former water course and its trail-like continuation		400
Total length of entire system of works from river to head		1,145

THE MAIN SEGMENT OF THE LONG BEAVER CANAL AT WINNECOOK, MONT., AFTER THE WEARING DOWN OF THE LEVEES: TAKEN LOOKING TOWARD THE RIVER FROM A POINT AROUND THE BEND TO THE SOUTH, A VIEW NEARLY SIMILAR TO THAT ON PLATE 2, FIGURE 2. NOTE REGULARITY OF CURVE.

Photograph by the author, August 25, 1918.

THE MAIN CANAL AS IT APPEARED WHEN FIRST DISCOVERED; LOOKING TOWARD THE RIVER FROM A POINT ON THE BIG BEND ABOUT 160 FEET FROM THE MOUTH OF THE CANAL. THE NARROW LEVEES SHOW FAIRLY PLAINLY.

Photograph by the author, July 29, 1916.

A SIMILAR VIEW OF THE CANAL FROM A POINT A LITTLE FARTHER TO THE SOUTH, TAKEN IN THE WINTER SEASON TO SHOW THE LEVEES PUSHING ABOVE THE MELTING SNOW.

Photograph by Thayer Stevens, winter of 1916–17.

1. ANOTHER VIEW OF THE PRINCIPAL SEGMENT OF THE CANAL AS IT APPEARED IN 1918; TAKEN FROM THE BEND LOOKING NORTH.

2. THE LONG SLOUGH FROM ITS NORTH END, SHOWING EMERGENCE OF THE BEAVER CANAL IN THE FORE PART OF THE PICTURE. THE DENSE GROWTH OF COTTONWOODS AND WILLOWS IN THE BACKGROUND WAS THE SCENE OF MUCH BEAVER ACTIVITY DURING THE OCCUPANCY OF THE SLOUGH AND CANAL.

Photographs by the author, August 25, 1918.

1. THE NORTHERN EXTREMITY OF THE CANAL WHERE IT PIERCES THE WILLOW-CLAD RIDGE BEFORE ENTERING THE RIVER.

Photograph by the author, August 25, 1918.

2. THE JUNCTION OF THE CANAL WITH THE MUSSELSHELL RIVER, THE CANAL ITSELF BEING SOMEWHAT OBSCURED BY THE BAR SILTED ACROSS ITS MOUTH. THE CANAL AT THIS TIME OPENED DOWNSTREAM TO THE LEFT OF THE BAR.

Photograph by A. W. Bell, August 25, 1918.

1. A SIMILAR VIEW TAKEN AFTER THE BEAVERS HAD AGAIN PIERCED THE BAR. THIS PICTURE PLAINLY SHOWS THE TEMPORARY DOWNSTREAM CONTINUATION OF THE CANAL JUST BEHIND THE BAR. A PORTION OF THE DAM FINALLY BUILT BY THE BEAVERS ACROSS THE CANAL A FEW YARDS BACK FROM THE MOUTH IS BARELY TO BE DISTINGUISHED.

Photograph by the author, August 12, 1921.

2. LOOKING NORTH ALONG THE MAIN CANAL IN 1921, SHOWING THE RESULTS OF THE FIRST EFFORTS OF THE BEAVERS TO CLEAR AWAY THE RUSHES AND OTHER GROWTH WHICH HAD ENGULFED THE OLD CANAL.

1. A BOARD LAID TO SERVE AS A FOOT BRIDGE ACROSS THE MAIN SEGMENT OF THE BEAVER CANAL PRODUCED A TEMPORARY BLOCKADE OF CANAL TRAFFIC; THE CRESCENTIC CUTS MADE BY THE BEAVERS AS HERE ILLUSTRATED SHOW A CURIOUS LACK OF COORDINATION IN THE EFFORTS DIRECTED TOWARD THE REMOVAL OF THE OBSTRUCTION.

Photograph by the author, July 29, 1916.

2. TRUNK OF A LARGE COTTONWOOD TREE, FELLED AND STRIPPED OF ITS BARK BY BEAVERS, STRANDED ON THE BANK OF THE MUSSELSHELL RIVER SOME DISTANCE BELOW THE BIG CANAL.

Photograph by the author, September 5, 1919.

THE REPUBLIC OF SALVADOR.

By Paul C. Standley.

[With 16 plates.]

Of the five Central American countries there is none so little known in the United States as El Salvador, the least in area of all the American Republics. It is not because of its small size that so little is known about it, but rather because of its somewhat remote geographic position, and moreover it often suffers innocently because of confusion of its name with that of a tiny island in the Bahamas. Mention the name Salvador to almost any American, even a person of presumably good education, and too often it evokes a remark, "Oh, yes, the island on which Columbus landed;" and when the Republic is, infrequently, distinguished from Columbus's first landing place, it is only too likely to be relegated to some indefinite location in South America.

That Salvador has been less visited by North Americans and is less known to them than the neighboring Republics of Guatemala, Honduras, and Nicaragua, results chiefly from the fact that it lies wholly upon the Pacific slope of Central America; it is the only one of these States that does not possess an Atlantic coast. It is, besides, rather difficult of access from the United States, except from California, and the only Americans likely to visit it are commercial travelers and a few tourists who land for a part of a day while their steamers lie at anchor to take on cargo at one of its three ports.

Salvador was explored in 1524 by Pedro de Alvarado, one of the associates of Hernán Cortés, conqueror of Mexico, who fought his way against the hostile occupants of the country until he reached their chief town, Cuscatlán, which was situated near the site of the present capital, San Salvador. Soon afterward permanent Spanish settlements were established, which now have a history extending over nearly four centuries—centuries of peace and quiet if we may judge by the scant accounts of them that have come down to us. Salvador's boundaries, like those of the other Central American States, have remained nearly always the same. More isolated than its sister countries from the ordinary trade routes, it passed a peace-

ful existence under the Spanish régime, and since that time its history has been somewhat less turbulent than that of some of its neighbors.

As seems to be the case with all small countries, the Salvadoreans are very loyal to their own land, and their loyalty and patriotism are based upon thorough personal acquaintance with their country, for standing upon almost any one of the mountains in which the land abounds, it is possible to view nearly the whole Republic, from the mountains of Guatemala to the west, along the great blue mountain wall of Honduras, to the peaks of Nicaragua which rise in the far distance of the east, beyond the Gulf of Fonseca. The Salvadoreans have always been the most enthusiastic advocates of the Central American Federation, the union of the five States as one government, which did exist for a series of years after the liberation in 1821 of Central America from Spanish dominion, and they were very bitter when at the end of 1921 the most recent attempt to resuscitate that union resulted in failure. A well-known traveler, John L. Stephens, sent by the American Government as a special minister to Central America at the time of the dissolution of the first Central American Federation, about 80 years ago, after having traversed the whole region between Guatemala City and the capital of Costa Rica, speaks of the inhabitants of Salvador, then fighting under the famous patriot, Morazán, against the Guatemalans, in the following words:

> From the time of the independence this State stood foremost in the maintenance of liberal principles, and throughout it exhibits an appearance of improvement, a freedom from bigotry and fanaticism, and a development of physical and moral energy not found in any other [Central American country]. The Salvadoreans are the only men who speak of sustaining the integrity of the Republic as a point of national honor.

The same characteristics are strikingly noticeable to-day. No other part of Central America except Costa Rica is so far advanced in political affairs and physical improvements. The country has the advantage of possessing a population that is industrious to a remarkable degree, progressive, and intelligent. There are few foreigners in Salvador, and the greater part of the wealth has remained in the hands of the native people. There is no negro population as in Guatemala and Honduras, and all the Indians have adopted the speech and customs of the Spanish conquerors. Formerly the Nahuatl language, a dialect of the idiom spoken in the Valley of Mexico, prevailed among most of the population, but it is now almost obsolete, except in the place names of the country, and in a large number of the words used for common household articles. Here as elsewhere in Latin America, Castilian Spanish has been extensively modified by the incorporation of words taken from the tongue of the

conquered people, just as the people themselves have nearly all been modified by the inheritance of Spanish blood.

The people of Salvador are noted for their independence, and there is among them nothing of the servility that characterizes the Guatemalan Indians. Although not quarrelsome, they are able and ready to maintain their rights, and do not submit easily to dictation. Although there are some large estates in Salvador, the country boasts of its great number of small landowners, and there exists here nothing of the peonage system that holds in practical slavery the inhabitants of some Latin American countries.

In area Salvador is slightly larger than the State of Vermont. Its population is about a million and a half, and it is probably the most densely populated country of the western hemisphere. The central and western departments are the most thoroughly occupied, and in these parts of the country one is scarcely ever out of sight of a dwelling. In the eastern portion, known as the Oriente, there are large tracts of unimproved land, much of which is given over to cattle raising.

VOLCANOES.

Since Salvador lies upon the western slope of the great cordillera that traverses Mexico and Central America, none of the elevated peaks of that chain lie within the country. Although almost everywhere mountainous, Salvador has no very lofty peaks, the highest reaching an elevation of slightly less than 8,000 feet. For what the mountains lack in size they compensate in their interest. Geologically Salvador is a great volcanic mass, with volcanoes rising on every side. Nowhere is one ever out of sight of a volcano, and nearly always there are several in the landscape. It is said that no other country possesses so many that have been active within historic times.

These volcanoes lie in an irregular chain that extends lengthwise of the country, parallel with the coast. Along the western side near the Guatemalan border lies the most sharply marked mountain range of Salvador, the Sierra de Apaneca. At one end of this small range stands the Volcano of Santa Ana, still feebly active, the highest Salvadorean mountain, at whose foot sprang up the Volcano of Izalco. To the eastward at irregular intervals, usually separated by level country, rise one after another the volcanoes of San Salvador, Cojutepeque, San Vicente, Usulután, San Miguel, and Conchagua, besides numerous lesser ones, while isolated clusters of small volcanic peaks occur here and there outside the principal chain.

The Oriente is a low country, with wide stretches of plains, but the central and western parts of the Republic are elevated and hilly

or mountainous. There is only one large river in Salvador, the Lempa, which traverses nearly the whole length of the country. There are several large lakes, occupying old craters, the best known of which are Güija, Coatepeque, and Ilopango.

Of all the natural features the volcanoes are no doubt the most interesting, and the history of the country is inextricably interwoven with their activities. They constitute one of the most active seismic regions of the globe, and their eruptions, resulting in great loss of life and damage to property, have been all too frequent in the last few hundred years. The Volcano of Santa Ana is quiescent at the present time, and its slopes are covered with rich coffee plantations; but formerly it was more active, and an eruption occurred in 1885. Its neighbor, the Volcano of Izalco, is the most interesting mountain of Central America, and has a history which is paralleled in interest only by that of the Volcano of Jorullo in Mexico. Accounts disagree as to the details of its development, but it is certain that it was not in existence in 1637, its site being occupied at that time by a mere fumarole or *ausol*, situated in the middle of a plain. According to some authors, its growth began about 1740, but according to others not until 1770. At any rate, its period of active development began abruptly, and after a violent outbreak that took place in 1798 it grew rapidly, attaining almost its present size within about 30 years. It now has an altitude of over 6,000 feet, and is a symmetrical cone of forbidding aspect, devoid of vegetation over the greater part of its slopes. It is still active, and an extensive flow of lava ran down its side in 1920. Smoke rises from the crater a great deal of the time, and flames are often seen at night, their frequence upon its summit, which is in full view from the sea, having given it the name of the "Lighthouse of Central America."

The Volcano of San Salvador, although not the highest, is the most important one of Salvador, because of its proximity to the capital, a city of some 80,000 inhabitants. San Salvador lies in a valley to which has been given the significant name of Valle de las Hamacas, "Valley of Hammocks." This valley has been rocked repeatedly by violent earthquake shocks, and a less persistent people would long ago have abandoned the site of the capital in despair—although, to tell the truth, it is hard to tell where in Salvador it would be possible to fix upon a site free from similar dangers. On several occasions it has been necessary to remove the seat of government temporarily to other parts of the Republic. Tremors of the earth, slight but sufficiently strong to be readily perceptible, are so frequent as to attract little attention. Not all of these, it is believed, are the result of action of this volcano, but some at least are thought to originate in

other centers, such as the vast crater in which lies the Lake of Ilopango.

Only two important actual eruptions of the Volcano of San Salvador are on record, the first of which took place in 1658, when a great flow of lava descended to the north, covering the village of Nejapa. This old lava field, though now overgrown with vegetation, is a conspicuous feature. In June, 1917, there occurred a second violent eruption, during which another large flow of lava was thrown out over nearly the same course as the former one, and fortunately not in the direction of the capital. This flow came from a vent on the side of the mountain, and not from its central crater, which is an immense circular pit, 1,260 feet deep. In the bottom of this crater prior to the outburst of 1917 there was a beautiful lake, but at the time of the eruption the water was thrown up in the form of vapor and precipitated as rain. The vapor must have been charged with acids or other deleterious substances, for the rain killed all vegetation upon which it fell. In the bottom of the crater, where the lake formerly existed, was formed a diminutive cone, about 300 feet high, in whose summit there is the most perfectly symmetrical crater imaginable. Eruptions of rock from this miniature crater continued for some time after the first violent outburst of smoke and flame, but they did no damage. The city of San Salvador was mostly destroyed by the earthquake accompanying the eruption, although there was little loss of life. In 1919 there occurred another violent earthquake, much more destructive to life than the first, but this was not accompanied by an eruption.

The Volcano of San Vicente, the second highest peak of Salvador, has not been active within historic times, but there lies at its foot a group of hot springs and fumaroles that indicate that it is not wholly extinct. Farther on, to the east, stands the Volcano of San Miguel, which, while only the third in absolute elevation, is by far the most imposing of Salvadorean mountains, on account of its symmetrical form and its isolation, and because it rises from a low plain. It has erupted several times, and at present there is nearly always a cloud of smoke and steam streaming like a plume from its summit.

AGRICULTURE.

The principal industry of Salvador is agriculture, and here agriculture is almost synonymous with coffee growing. Coffee is cultivated everywhere at altitudes of 1,000 feet or more, and it is often planted right up to the summits of the highest mountains. It is the chief source of the wealth of the country, and the annual exportation amounts sometimes to over $12,000,000 a year. The ex-

portation of so great a quantity of a staple article entails a large trade balance in favor of the country. Coffee plantations lend a pleasing aspect to the landscape, and give the impression of the existence of primeval forest in a region where all the natural covering of trees was removed years ago. The coffee plant is a denizen of the forest and requires shade for protection from the sun, hence it is necessary to plant trees for its shade. Unless familiar with coffee cultivation, one may travel for miles through a region given over to its growth and yet be unaware that the land is actually under cultivation, for the coffee bushes are scarcely noticeable beneath the shade trees, unless they happen to be loaded with the clusters of spicy-fragrant, waxy-white blossoms that they bear for a few days of the year.

It is fortunate for Salvador that the prevailing crop is such a one as coffee and not wheat or corn, which would necessitate complete clearing of the land. In spite of their substantial appearance, many of the hills and mountains, like most of the plains, are nothing but beds of volcanic ash, finely packed, and so hard in a vertical exposure that they are almost unaffected by weathering, but when cleared of vegetation they sometimes melt away after heavy rains almost like snow. In certain parts of the country the hills have been greatly eroded by running water and rain, resembling the "bad lands" of the western United States. Enormous gullies, several hundred feet deep, are separated by knifelike walls only a few yards in thickness, which gradually—and not too gradually—dissolve away. If it were not for the extensive planting of trees necessary to shade the coffee plantations, the whole country would shortly become unfit for cultivation, and in no part of the earth is there greater need for conservation of trees and other natural vegetation, or for efficient substitutes for them.

The Salvadorean climate is tropical, but it does not altogether satisfy the generally accepted ideas of what a tropical climate ought to be. It is hot in the lower parts, but in the mountains it is delightfully cool and pleasant. The most marked feature of the climate is the division of the year into two seasons, dry and wet. From April until the end of October there are frequent rains, and often heavy ones. Sometimes there are *temporales* or prolonged rainy periods that last as much as two weeks, but in general there are brief showers almost every day or night, with good weather the greater part of the time. It is during the rainy season that most of the crops other than coffee are planted and cultivated. From the first of November to April there is no rain, except for an occasional insignificant shower. Soon after the cessation of the rains the ground dries, and only a few days elapse before the roads are deep in dust.

The dust, which pervades everything, lends to the dry season its characteristic and all too perceptible atmosphere. In most Salvadorean roads there are few stones, and the result is that there seems to be almost no bottom to the dust. During the dry season, which corresponds to our winter—strangely enough, the Salvadoreans call it summer—cultivation of most crops can not be carried on for lack of water. In some places irrigation has been established, and there corn and other crops may be seen in all stages of growth at any time of year.

Although coffee is the most important Salvadorean product, other substantial crops are grown, chiefly for food. Sugar cane is cultivated extensively in the less elevated parts and some sugar is exported. Formerly indigo was the chief export crop, and huge amounts were shipped annually; but its cultivation has now declined because of the use of coal tar dyes, and only a little is produced. The most important food crops are corn, beans, and rice. Corn and beans, the latter a peculiar small black sort, are the articles of food which appear upon every table at every meal, in the homes of both rich and poor, just as throughout Mexico and Central America and in some portions of the southwestern United States. Rice is almost equally important. That grown in Salvador is of the upland variety, which does not require flooding for its development but is planted and tilled like wheat or oats.

Vegetables are grown in great variety, and San Salvador especially has a favorable location for obtaining a continuous supply of fresh vegetables and fruits. The city lies at an altitude of slightly over 2,000 feet, making possible the growth of all sorts of tropical plants in the immediate vicinity, while rising above the city is the Volcano of San Salvador, over 6,000 feet high, on whose slopes, where the climate is cool and comparatively moist, most of the plants of temperate regions can be grown. Practically all the common vegetables of the United States are cultivated, besides some that are not known here. Such is the *yuca*, a close relative of the cassava plant from which the people of some parts of South America obtain their principal starchy food and from which tapioca is prepared. Yuca is grown for its roots, which resemble sweet potatoes and are used in the same way. In texture they are firmer and somewhat waxy, and their flavor is very good. One of the commonest vegetables is the *chayote* or *huisquil*, a relative of the cucumber. The plant is remarkable in that all its parts can be utilized for food. The tender green fruits are boiled and eaten, the young branches are cooked as a pot herb, and the large fleshy roots also are edible, serving as the basis of a peculiar and delicious sweetmeat. Cabbage, cauliflower, turnips, and other vegetables that are associated with cool

climates thrive. Irish potatoes are not used extensively by the common people of Central America, but they are grown on the slopes of the volcanoes. Most of those produced are scarcely larger than walnuts.

FRUITS.

It is in the abundance of fruits that tropical countries surpass temperate regions, although it must be confessed that in the United States we have available the best of the tropical fruits. In all our markets it is possible to obtain cheaply the orange, grapefruit, pineapple, and banana, and with these we have the finest of all the American tropical fruits, with the exception of the avocado and perhaps the mango. There are dozens of others that are grown in the Tropics, but it is doubtful whether they would ever become popular in competition with the best fruits of temperate regions, no matter how abundant they might be. The most marked character of the majority of tropical fruits is sweetness, and many of them have no other merit. It is not uncommon in Central America to hear the remark made that such and such a fruit is very good because it is so sweet.

The mango is probably the favorite fruit in Salvador and is grown everywhere. It is too well known to need description, the turpentine flavor and superabundance of fiber in the inferior varieties being matters of rather general knowledge. The best mangoes are really very good, competing in quality with peaches, which they distantly resemble. I have heard working people say in Salvador that when mangoes were in season they never had to spend a cent for food, and it is certain that enormous quantities are consumed. Avocados are grown commonly, but they are scarcely equal to those of Guatemala. Numerous kinds of anonas, soursops, and custard apples are cultivated, and the country has the distinction of producing the very best of these, the white anona (*Annona heterophylla*), a variety known only from this country and Guatemala. Salvador produces large quantities of excellent oranges, similar to those of Florida but much sweeter. Pineapples, often of exceptional size, are common, also limes, pawpaws, sapotes, sapodillas, and mameyes. There is an almost unlimited list of minor fruits, most of which are unknown in the United States, such as the *sunzapote* (*Licania platypus*), a large yellow-fleshed fruit of little merit; the *marañón* or cashew fruit (*Anacardium occidentale*), whose seeds are roasted and used like almonds, while the fleshy stalk beneath the seed is eaten as a dessert fruit; various kinds of *granadillas*, the fruits of species of passion-vines (*Passiflora*); the *icaco* (*Chrysobalanus icaco*), a flavorless white-fleshed black-skinned fruit; the *aceituno* (*Simaruba glauca*), which is equally flavorless, and re-

sembles an olive in appearance; the rose-apple or *manzana rosa* (*Eugenia jambos*), a curious small crisp yellowish fruit, little esteemed, with a flavor suggesting scented toilet soap; and dozens of others, wild and cultivated, which it would not be of interest to mention here.

By far the most extensively grown fruits of Salvador are the banana and plantain, for these are important articles of food among all classes. Salvador is the only Central American country in which bananas are not grown for export to the United States. Although there are no large plantations of them, such as those of Guatemala and Honduras, small patches are planted in every finca, and I suppose that the banana plants are really the most characteristic feature of the vegetation of the country, for, indeed, one is almost never out of sight of them. Bananas and plantains are much alike in general appearance, but the fruit of the plantain is larger and coarser and eaten only when cooked. There are several common varieties of bananas, but the one most esteemed for eating raw is that which is so universally seen in the United States. Some of the varieties are too coarse for eating raw, like the one called *majoncho*, which is the kind most commonly grown.

Besides these tropical fruits, most of those of temperate regions are cultivated upon the higher mountains. On the Volcano of San Salvador there are apples, peaches, grapes, strawberries, quinces, and cherries in cultivation, but except for the strawberries it can not be said that they are cultivated successfully. The peaches and apples are small and of inferior quality, owing perhaps to the planting of unsuitable varieties. Strawberries of good quality are produced and may be had throughout most of the year. One of the more unusual fruits cultivated upon the volcanoes is the *pepino* (*Solanum muricatum*), a plant closely resembling the common potato plant. It has large blue flowers which are followed by egg-shaped fruits, yellowish and striped with purple, that are eaten as a dessert fruit.

The high slopes of the volcano of San Salvador are the source of most of the flowers with which the markets of the capital are lavishly supplied. In the early morning it is common to see files of women coming down from the volcano, bearing upon their heads baskets of fruits and vegetables, eggs, chickens, and turkeys, and many other articles, and not a few of them bring baskets of freshly gathered flowers. Nowhere do roses flourish better than in Salvador, and I have seen a single plantation of over 800 bushes all loaded with blossoms. Dozens of bunches of violets are brought every day to the markets, and great quantities of fragrant white lilies. Nearly all our common garden flowers are cultivated, besides many that are rare or unknown here, or are seen only in the gardens of

Florida and California. After having seen cultivated in hothouses of our country so many of the native plants of Central America, it is interesting to see grown in Salvador some of the native plants of the United States, like the gaillardia and the California poppy.

VEGETATION.

The botanical features of Salvador are those in which the writer is most interested and to which he has devoted most attention. Two of the Central American Republics, Guatemala and Costa Rica, are fairly well known botanically, but until 1921 scarcely any plants had been collected in Salvador, and practically nothing was known of the flora. The writer spent five months there, visited nearly all parts of the Republic, and made a comprehensive collection of the plants.

The flora is not so diversified as those of the neighboring countries. The area of Salvador is small, and its surface is less varied than that of any other Central American State. Moreover, the greater part of its surface, and particularly that portion which is naturally the most interesting botanically, is under cultivation. The mountain slopes, where the most interesting plants would be expected, are nearly all occupied by coffee plantations, and in many localities almost all the natural vegetation has been destroyed. Nevertheless in nearly all parts it is possible to find small tracts of land that are so rough or otherwise unfit for cultivation that they have been left in their natural state, and in these spots one can form some idea of the conditions originally existing. In eastern Salvador there are large areas whose vegetation has been little or not at all changed by man, but these lie at a low altitude, and in tropical countries generally the plants of low elevations are pretty certain to be less interesting than those found in the mountains. The low-altitude plants are likely to be widely dispersed species, many of them of a weedy nature, while in the mountains there are great numbers of localized plants.

The flora of Salvador is like that of western Guatemala, and probably closely related to that of Pacific Nicaragua, although practically nothing is known of the latter. Study of the collections recently obtained indicates also that the flora bears a close relationship to those of western Costa Rica and Panama, and there are numerous plants in these collections which previously were not known to occur north of those countries. So little is known at present of the Central American flora as a whole that it is impossible to speak with real authority upon the relationships of the floras of the different regions.

In general, the vegetation of the Pacific slope of Central America is less rich than that of the Atlantic slope, largely because of the

difference in rainfall. The Atlantic slope is very wet, while the Pacific slope is comparatively, and often absolutely, dry. All of Salvador lies within this dry region, and there are not found here the heavy rain forests that characterize the Atlantic slope, especially on its higher mountains. At the present time there are no dense Salvadorean forests of great extent, and perhaps there never were any. It is true that in some parts of the coast there are primeval forests, composed of large trees, but the trees are not nearly so closely spaced as in regions where there are heavier rains. Upon the slopes of some of the mountains there still remain forested areas, but seldom of great extent. The most important forest tracts still remaining are those of the Sierra de Apaneca, near the Guatemalan border, but these are being rapidly destroyed to make way for coffee, and the small areas of virgin forest remaining on the Volcano of San Vicente are meeting a similar fate. Upon the Volcano of San Salvador nearly all the big trees have been destroyed, and even the small ones are burned for charcoal, leaving only brush in the parts of the mountain unfit for cultivation.

It is difficult to give a brief account of the general appearance of Salvadorean vegetation, because of the changes that have been wrought by man. The coastal region, which includes the eastern part of the country and a strip of varying width extending all along the coast, and up the valleys of the streams, is characterized by a rather thin forest which consists largely of species which lose their leaves during the dry season, so that during the winter months the forest is little greener than a deciduous forest of the North Temperate Zone. Many shrubs are interspersed among the trees and frequently form dense thickets, although in places where conditions are not favorable for their growth the plant covering is sparse. Trees and shrubs that bear spines are particularly common, and the general aspect of the vegetation is like that of the coastal plain of western Mexico, especially in the State of Sinaloa. Along the beach are found the plants that are characteristic of such locations throughout the American tropics, nearly all of them species of wide distribution, such as the mangrove (*Rhizophora mangle*), the black mangrove (*Avicennia nitida*), and manchineel (*Hippomane mancinella*). The mesquite (*Prosopis juliflora*) is rather common in the coastal plain, but is rare or wanting in other parts of Salvador.

At middle elevations most of the large trees have been removed, except some left for shade because their wood is useless, but there are seen here and there on sterile areas thickets composed of a wide variety of shrubs. The best place in which to find plants in this region is in the hedges, which are so prominent a feature of the Salvadorean countryside. Fences of wire are not often seen, but the

fields are separated by dense hedges in which the native plants also find their only refuge. The number of plants grown for hedges is almost endless, but among the most common are pineapples and another plant of the same family, and nettle trees of various kinds, notably one known as *chichicaste* (*Urera baccifera*), which stings the flesh painfully on contact. In most parts of Salvador there are miles of hedges composed of a tree cactus (*Pereskia autumnalis*) known as *matial*. This plant attains a height of 20 feet or more, forms a dense growth, and is covered with long slender spines. It is one of the most repellent plants that can be imagined, and it is most unpleasant to have to pass along a road lined with it, especially when the wind is blowing, for there is always danger from the minute spines that are borne upon the stems and are carried about by the wind. *Matial* hedges are undesirable from nearly every point of view. They occupy a great deal of ground that might be utilized for more productive purposes, and they are dangerous to domestic animals, but nevertheless they seem to be popular.

In these areas at middle altitude there are often to be observed considerable stretches of grassland, such as those about San Salvador, upon the slopes of the volcano and on the sides of the Cerro de San Jacinto, which stands near the city. These are used as pasture. Near Ahuachapán is a curious tract of land, called the Llano, almost devoid of bushes but carpeted with a close greensward scarcely 2 inches high, composed wholly of a single kind of grass. The Llano also is used as pasture, and it has the appearance in winter of a well-kept lawn.

Upon some of the higher mountains there are dense growths of trees, representing a large number of species. The mountain forests consist almost exclusively of broad-leafed trees, most of which retain their foliage the entire year, although actually they shed the old leaves gradually, putting forth new ones at the same time. In a few places there are small pine forests, such as those upon the hills about Santa Ana, the Volcano of Conchagua, the crater of the Volcano of San Salvador, and the mountains along the Honduran frontier, but pines are so scarce as to be of almost negligible economic importance. No other plant of the pine family is native in Salvador.

The mountain forests consist chiefly of trees which have no close relatives in the United States, but there are a few which are familar. At the highest elevations several kinds of oaks are frequent, also a fine large elm (*Chaetoptelea mexicana*), and among the undergrowth are found viburnum and blackberries. Epiphytic plants are common throughout Salvador, but are particularly abundant in the high mountains, where the tree trunks are covered by

various "air plants," such as orchids, ferns, aroids, bromeliads, lichens, and mosses.

The Salvadorean flora is not rich in ferns, and ferns are not ordinarily conspicuous features of the vegetation. Tree ferns are very rare, although at least three species occur. One of these (*Cibotium guatemalense*), growing high up on the volcano of San Salvador, has the young leaves or croziers covered with long hairlike yellowish scales resembling fur. Bunches of these, known as *micos* ("monkeys"), are sold in the markets for decorations. Around San Salvador tree ferns must have been common formerly, although now only a few small sterile plants are to be seen. In the Sierra de Apaneca there are beautiful ferns with tall, slender trunks, but they are being rapidly exterminated.

The widespread belief that tropical forests afford vivid color displays, composed of vast flocks of parrots and other bright-colored birds, and great masses of brilliant-hued orchids and other flowers, an impression obtained by reading overenthusiastic descriptions in popular works of fiction written by persons who knew nothing of the Tropics, has so often been shown to be false that it is probably not so widespread as it once was. The forests of Salvador are of rather gloomy aspect, and it is only now and then, at favorable times of the year, that fine vistas of color can be seen. Nowhere in that country did I observe any color display that would compare with the flower fields to be seen anywhere in the Rocky Mountains in August or those to be found in late summer in the mountains of North Carolina. For sheer wealth and intensity of color I suppose nothing can equal the miles and miles of fields of solid yellow common in the Mississippi Valley in late summer when the beggar's ticks or Spanish needles are in full blossom.

Orchids grow in Salvador, but there do not appear to be many species, and few of them are showy. There is one, however, that fulfills all one's preconceived notions of tropical orchids. This is the one known locally as *flor de San Sebastián* and botanically as *Cattleya skinneri*. The Cattleyas are the largest and handsomest of hothouse orchids, and this species is one of the finest. It grows nearly everywhere, and forms clumps as large as a bushel basket placed high up on the tree branches. In spring the plants are covered with flowers and form masses of color that may be discerned at a long distance. The flowers—or the whole plants, for that matter—are brought to the markets, where they bring prices that seem ridiculous in comparison with those paid for scarcely superior hothouse flowers in the United States.

Much more showy than most orchids are the bromeliads (plants of the pineapple family), which are often mistaken for orchids. Some

of these are common in Florida, and one of the best-known representatives of the family is the Spanish moss that festoons the trees of the Southern States. Bromeliads are much more common than orchids in Salvador and grow at all altitudes. The large flower spikes are usually pink or bright red and the flowers themselves some vivid shade of blue.

Other epiphytic plants common here are the aroids, to which belongs the common caladium or elephant-ear. Some of the members of this family grow upon the ground, but most of them cling to the branches of trees, and are vinelike in habit. There are many kinds of them, but they are mostly confined to the mountain forests, especially along streams. These plants are remarkable for the polymorphism of their leaves, the young plants often being so unlike adults that it seems almost impossible there can be any relationship between them. The young plants often have remarkably handsome leaves, with metallic sheen or tinted with pink, and for this reason are grown in northern hothouses. Some of the aroids, especially those of the genus *Monstera*, are noteworthy for the form of their adult leaves, which are perforated with large round holes. Not a few of the Salvadorean aroids have edible fruits, but care must be exercised in eating them because of the needlelike crystals contained, these causing a painful sensation to the tongue.

TREES.

It is among the trees that the most important native Salvadorean plants are found, and of these none is more interesting than the balsam tree (*Toluifera pereiræ*), which produces the article known as Peruvian balsam. This leguminous tree ranges from Mexico to northern South America, but it is most abundant in a limited part of Salvador, known as the Balsam Coast, and practically all the commercial article comes from this region. The Balsam Coast lies mostly in the Department of Sonsonate, where the trees occur abundantly in the low mountains, growing in thin forest. The tree is a handsome one, with a very tall but slender, straight, pale, smooth trunk and a small open crown. It is of slow growth, and the wood is fine and hard. The leaves are furnished with innumerable small oil glands that are easily visible when a leaf is held to the light, and the curious winged fruit is filled with large glands from which oil oozes when the fruit is crushed.

The balsam is sometimes obtained from the fruits by crushing, but most of it is secured by tapping the trunk. Over a small portion of the trunk the bark is crushed, and upon these injured parts rags are placed and left for some days, becoming thus saturated with the balsam that runs out. The rags are collected and the liquid is

expressed and later refined by a boiling process. The balsam is an official drug in the United States Pharmacopœia, being employed in the treatment of diseases of the respiratory system, and in Europe it is used in the preparation of perfumes and other articles. By a papal bull issued by Pius IV in 1562 and by another by Pius V in 1571 the clergy were authorized to use the balsam in the preparation of the chrism, and it was declared to be a sacrilege to injure or destroy the trees. The balsam is still much used in church services.

In spite of its name of Peruvian balsam, the tree which produces it is not found in Peru. This erroneous term owes its origin to the fact that in colonial days the balsam sometimes found its way to Spain by way of Peruvian ports. When first introduced into Europe the most extravagant properties were ascribed to it, and it sometimes sold at as much as $200 an ounce. Although apparently native only in a restricted portion, cultivated trees are seen in all parts of Salvador. It is said that these cultivated trees will not yield balsam; but while this actually may be the case, it seems most improbable.

The national tree of Salvador undoubtedly is the *amate*, or wild fig. Of the wild figs there are numerous species, all with fruits in form much like those of the cultivated fig tree, but usually small and inedible. The *amates* are not lofty trees, but they are strikingly handsome, with short, thick trunks and broad, spreading crowns of lustrous foliage. The familiar banyan trees of the Orient are of this group, but I did not see any trees of the banyan type (with numerous trunks extending down from the branches) in Salvador, although they are common enough along the western coast of Mexico. The wild figs frequently begin their existence upon the branch of some other tree, where the seed germinates, and later the young fig plant develops long aerial roots that reach down to the ground and take root. The intruder grows rapidly and soon envelops and destroys its foster parent. The *amates* are probably the most admired of all Salvadorean trees, and they are left for shade everywhere along roads and in fields. There is scarcely a country dwelling that does not boast of its special tree, which is frequently quite as much a center of domestic activities as the dwelling itself.

Another tree which vies in beauty and interest with the *amate* is the *ceiba*, or silk-cotton tree, of which there are fine examples in many places. The *ceiba* is not nearly so abundant as the *amate*, but it is a much larger and more imposing tree, being actually, I believe, the largest Salvadorean tree. The trunk is often of enormous girth, but not very tall, and the crown is large in proportion, not high but of ample spread. The trunk is usually strengthened at the base by buttresses, which radiate on all sides and supply the strength necessary to sustain the great top. The *amate* trees also, when they have attained a large size, sometimes develop buttresses.

The flowers of the *ceiba* are small and inconspicuous and the tree has the disadvantage of shedding its leaves during the dry season. The fruit is a capsule whose seeds are surrounded by a beautiful lustrous silklike fiber that is useful for stuffing pillows. The wood of both the *ceiba* and *amate* is useless except for fuel, and even for this it is unsatisfactory; and I suspect that to this fact these trees owe their great abundance.

The trees that excel all others in the matter of showy flowers are two species of *Tabebuia*, a group of plants closely related to our catalpas, with flowers of about the same size and form, but with quite different leaves. Both these trees have the defect of producing their flowers when leafless, but they bear their blossoms in such profusion that even if the leaves were present they would scarcely be noticeable. One of the Tabebuias (*T. chrysantha*), known by the name of *cortez*, bears large bunches of bright yellow flowers. The *cortez* is found mostly at low altitudes, and, while it is extremely showy when in flower and is not rare, I have not seen any particularly noteworthy displays of it. The other tree (*Tabebuia pentaphylla*), which is known by the name *maquiligua*, is in a class by itself so far as display of color is concerned. The trees are often large, and in spring, near the end of the dry season, become giant bouquets of pink blossoms. They are found throughout the country, dotting the landscape or occurring in groves as far as the eye can reach. In color effect they simulate Japanese cherries, for they exhibit the same variation in tints, from nearly white to a deep rose-pink. Aside from their esthetic value, both the *maquiligua* and *cortez* are of economic importance, since they furnish excellent cabinet woods that are much used locally.

There is another tree that in some localities is almost as showy as the Tabebuias, although far inferior in beauty of color. This is the *palo mulato* (*Triplaris americana*), also a valuable timber tree, which, strangely enough, belongs to the same family as buckwheat and smartweed, a group of plants which, as they occur in the United States, have few claims to beauty and do not with us attain the size of trees.

The *palo mulato* is particularly abundant about Santa Ana, where it is planted extensively in the fincas, and in February the whole valley, as viewed from a hillside above, is colored crimson and pink with it. The trees are of two sexes, and it is only the female or pistillate ones that are showy. In the case of these, it is not the flowers but the fruits, with their envelopes, which produce the vivid color effects. The *palo mulato* maintains its color display much longer than the *maquiligua*, until the fruits fall. These are curious structures, the seed being overtopped by three paddle-shaped ap-

pendages that spread obliquely and form a sort of parachute, which bears the seed through the air. When one of the fruits falls it is not carried to any great distance unless the wind is blowing strongly, but as it drops it spins about like a top and floats gently to the ground. There is one other Salvadorean tree (*Gyrocarpus americanus*) known as *lagarto* or "alligator" that has a fruit almost exactly similar, although much larger and not colored.

One of the showy trees is the *madre de cacao* (*Gliricidia sepium*), which owes its name, "cacao-mother," to the fact that the inhabitants of Central America discovered centuries ago that for some reason the cacao plant throve better in its shade than in that of any other tree. Little cacao is grown in Salvador, but the *madre de cacao* is here in great profusion, being in fact the most common and characteristic tree of dry hillsides at low and middle elevations. The wood is valuable, especially for its resistance to weather, and the tree is often planted for living fence posts. When in blossom it is devoid of foliage but thickly clothed with clusters of pale pink flowers. Except in color, the blossoms are like those of our black locust, to which the Central American tree is closely related.

Of the same family (Leguminosae) is the tree known as *pito* (*Erythrina rubrinervia*), which is never very large and often but a shrub. It is an ungainly thing, irregular in form, with only a few clumsy branches, which are tipped with bunches of bright scarlet blossoms, followed by pods that contain several red seeds. The seeds contain a narcotic poison, and something of their properties appears to exist also in the flowers, which in their season are gathered in considerable quantities and used for food. They are boiled or fried with eggs and are quite palatable, resembling string beans in flavor. It is said that if they are eaten in quantity they cause marked drowsiness, and in view of the known properties of the seeds this seems not unlikely.

There are several trees and other plants whose flowers serve as food in Salvador. Most conspicuous of these is the *izote* or yucca (*Yucca elephantipes*), a plant of the Spanish bayonet type, which attains the stature of a good-sized tree. The ample panicles of creamy blossoms are seldom left to attain perfection, but are nearly always cut when tender, and fried with eggs and eaten.

One of the very best of Central American products that I have tested is the *pacaya*, the inflorescence of a dwarf palm (*Chamaedorea* sp.) of the same name that is common in all the higher mountains. The inflorescences are surrounded by a green spathe in such a way that they closely resemble small ears of corn. When dipped in egg and fried they are tender and have a delicious, agreeably bitter flavor.

Salvador is not rich in species of palms, and except for coconuts these tropical plants are not often dominating features of the landscape. Coconuts are abundant at lower altitudes, and the towns of Sonsonate and San Vicente are especially distinguished for their wealth of these most graceful of all tropical trees. The *coyol* (*Acrocomia vinifera*) is common in many places. It has plumelike leaves and hard round fruits which are more or less useful. Around Conchagua and in some other places there are groves of fan palms, whose leaves are employed for weaving hats. In the coastal country there are too frequent thickets of *huiscoyol* (*Bactris subglobosa*), one of the most pernicious plants in existence. It is a shrubby palm, growing in clumps, and armed everywhere with long, dark-brown spines that have points as sharp as needles. *Huiscoyol* thickets are literally impenetrable. The fruits are edible—more than that can not be said of them. At the little fishing village of Olomega boys and grown men were gathering big bunches of them and cracking the nuts to get the white kernels, for which they showed marked relish. They insisted upon my trying them, and I found them of about the consistency of aspen wood and equally delightful in flavor.

The trees that produce cabinet woods are almost without number. Mahogany is found, although not now very plentiful. The mahogany of the western coast is of a different species from that occurring in eastern Central America, and grows on dry hillsides, while that of the Atlantic coast is a swamp tree. Mahogany is so common in Central America that it is treated with scarcely more consideration than is hard pine in the United States. Beautiful ebony, hard and almost jet black, is furnished by one or more trees. From the *conacaste* (*Enterolobium cyclocarpum*) or ear tree, whose fruits are coiled in such a way as to resemble an ear, and from the *cuapinol* (*Hymenaea courbaril*), which also produces a gum useful for making varnishes, are obtained valuable woods, and the list might be continued indefinitely.

ANIMAL LIFE.

In a country so thickly settled, most of the larger animals have long since disappeared, and in Salvador there is no danger from the savage beasts that are popularly supposed to infest tropical lands. Jaguars and pumas, I believe, still are found in remote regions, but tapirs have been nearly or quite exterminated. Deer are plentiful in some localities, and tame fawns are often kept as pets. The largest wild mammals that I saw were rabbits, and only two or three of them. Parrots of a few kinds are abundant locally, but not often very conspicuous. To one who is not an ornithologist the other birds are not particularly interesting, except the turkey vultures or *zopes*,

which constitute the unofficial street-cleaning departments of tropical American towns.

There are many alligators in some of the lakes and in the rivers, and they are hunted for their skins and flesh. The giant lizards, known as *iguanas* and *garrobos*, are common in the low country, especially in the vicinity of San Miguel. In some settlements their flesh is used for food, while in others its use is scorned. The eggs of these lizards are often eaten. That snakes exist in Salvador can not be denied, and authentic accounts of deaths from their bites are not rare. In five months in the country, most of which was spent in tramping about in thickets and woods, I saw three or four small ones, all harmless. Rattlesnakes occur in places, likewise the coral snake and the deadly *tamagaz*, known elsewhere as the bushmaster or fer de lance. In general, I should say that the Salvadoreans take about as great precautions against serpents and think as much about them as do the people in any part of the United States.

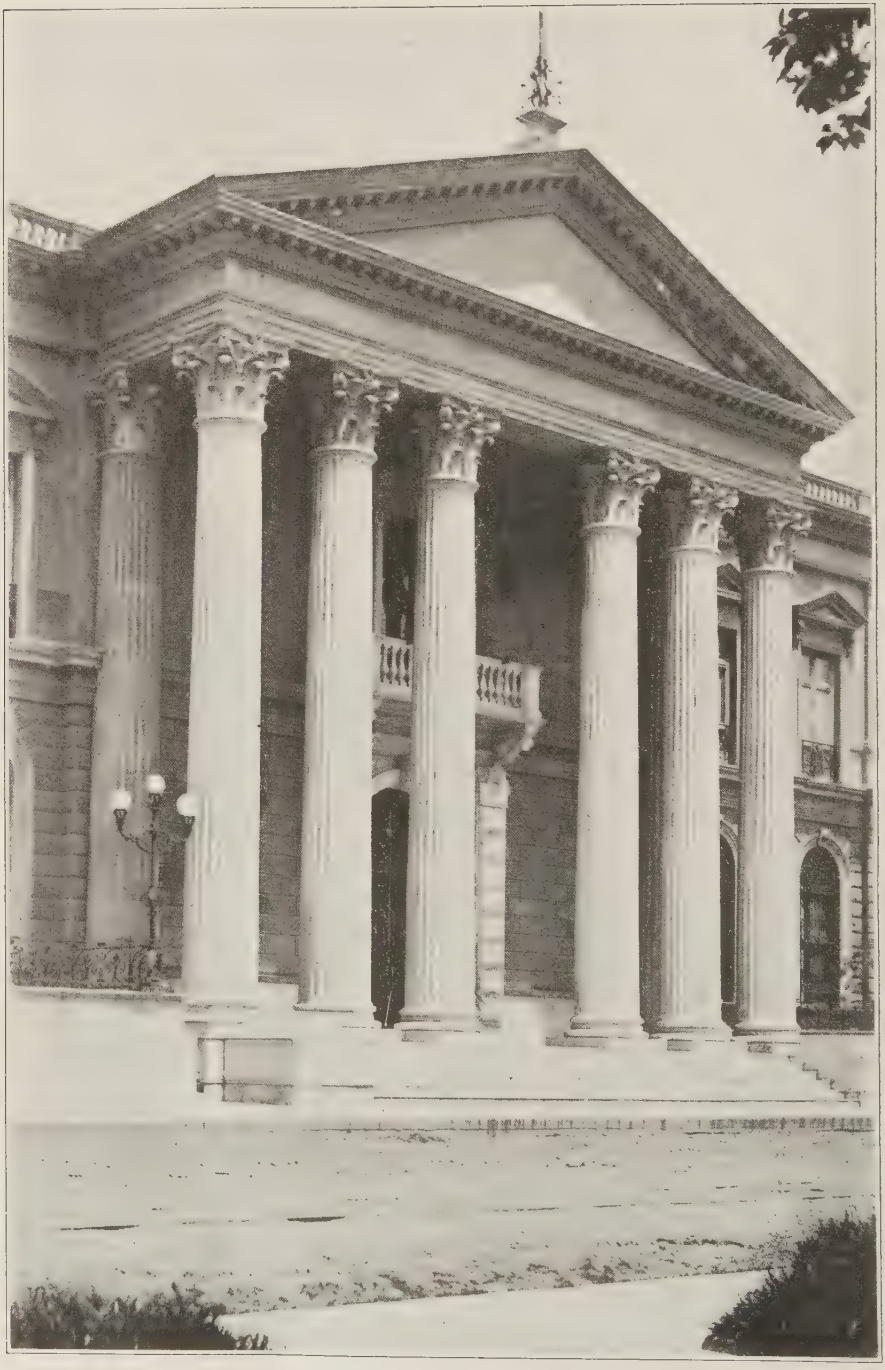
To one who has to go out into the rural districts it is not the snakes that give concern but the insects and their relatives. Of these Salvador has its full share, but none of them to so troublesome a degree as some other countries. The worst of the insects, for they are most universal and persistent, are the ants. Salvador must possess a remarkable variety of them, from the big *zompopos* or leaf-cutting ones, which delight in stripping of their leaves and blossoms one's most cherished trees and shrubbery, to the little *locos*, harmless insects that seem to pass their whole existence in aimlessly darting from spot to spot in such a manner that they well deserve the term "crazy" applied to them. Most of the ants can bite, and do so with little or even no provocation, and in some cases their bites are poisonous, at least to certain persons. One of the most vicious kinds frequents the wet sand at the edge of streams, and security from them can be obtained only by walking in the stream itself. Another ferocious sort inhabits the hollow spines of certain species of *Acacia*. Wasps are plentiful but not nearly so abundant as on the northern coast of Guatemala. Even worse than the ants at times are the *garrapatas* or seed ticks, much smaller than our wood ticks (which also are found in Salvador), and occurring in myriads in favorable regions, especially those where cattle are pastured. The ticks are so tiny that it is hard to find them upon the body, but their effects leave no doubt as to their presence. Ticks, however, are not found at higher altitudes, and even in the low country one may go for days without accumulating any. Nowhere in Salvador did I find them in such profusion as on the western coast of Mexico, where they sometimes make the work of collecting plants almost unbearable. The ticks, as I have said, do not ascend far into the mountains, but their

place is taken by a creature called *coloradilla*, which from its effects is probably the same as our red bug or chigger. The true chigger or *nigua* is common in Salvador—a pernicious flea which burrows into one's toes and does serious damage if not promptly removed, but one who wears shoes is not likely to be bothered by *niguas*.

In all tropical American countries the animal that is the most dangerous and usually the only one that is a serious menace to life is one of the smallest and most innocent-appearing—the mosquito. Without mosquitos there would be no malaria, and malaria is the worst scourge of the Tropics, at least for foreigners, since yellow fever has been so nearly eradicated. In nearly all parts of Central America malaria is prevalent, and Salvador is no exception. Because the climate here is comparatively dry, malaria is not so common as upon the north coast, but it is nevertheless still sufficiently prevalent. It can be avoided by protection against mosquito bites, and one who is careful always to sleep beneath a net runs little chance of contracting the malady. In Salvador I saw very few mosquitos during the dry season, but they are reported to be more numerous after the rains begin. Only by extermination of the insects would it be possible to control the disease, and this is impossible. Amœbic dysentery is another dangerous disease of tropical American countries, but it does not seem to be very common in Salvador. In general the country is a rather healthy one, the result in large part of the labors of an efficient health service, supported in substantial part by the Rockefeller Institution, which maintains here an agent, especially for assistance in control of the hookworm disease. Of all American influences in Salvador there is no other that is so disinterested, so utilitarian, and so appreciated as this work of one of our great scientific organizations, whose operations must be a matter of deep satisfaction to all Americans who have observed its practical field work.

PORT OF LA LIBERTAD.

Photograph from Pan American Union.



NATIONAL PALACE, SAN SALVADOR.

SCENE IN THE PORT OF LA LIBERTAD.

Photograph from Pan American Union

1. VIEW OF THE VALLEY OF THE RIO ACELHUATE, SAN SALVADOR, A PORTION OF THE CERRO DE SAN JACINTO IN THE DISTANCE.

2. A PARK (FINCA MODELO) IN SAN SALVADOR.

1. VOLCANIC ROCKS ALONG THE COAST, DEPARTMENT OF LA LIBERTAD.

2. CAVE IN THE CLIFFS OF THE COAST, DEPARTMENT OF LA LIBERTAD.

Photographs from Dr. V. M. Huezo.

1. TYPICAL THICKET OF THE COASTAL REGION, DEPARTMENT OF LA LIBERTAD.

2. LAGOON ALONG THE COAST, DEPARTMENT OF LA LIBERTAD.

Photographs from Dr. V. M. Huezo.

1. A CAVE WITH OVERHANGING FERNS, DEPARTMENT OF LA LIBERTAD.

2. CLIFF WITH SUPPOSED INDIAN HIEROGLYPHS, DEPARTMENT OF LA LIBERTAD.

Photographs from Dr. V. M. Huezo.

1. ERUPTION OF THE VOLCANO OF SAN SALVADOR, JUNE, 1917.

2. CRATER AND LAKE OF THE VOLCANO OF SAN SALVADOR BEFORE THE ERUPTION OF 1917.

Photographs from Dr. V. M. Huezo.

1. VIEW OF THE CRATER OF THE VOLCANO OF SAN SALVADOR DURING THE ERUPTION OF JUNE, 1917. THE PALE RING INDICATES THE EXTENT OF THE CONE FORMED DURING THIS ERUPTION.

2. A VIEW OF THE CRATER A FEW SECONDS LATER.

Photographs from Dr. V. M. Huezo.

1. CRATER UPON THE SIDE OF THE VOLCANO OF SAN SALVADOR, FROM WHICH ISSUED THE LAVA FLOW OF JUNE, 1917.

Photograph from Dr. V. M. Huezo.

2. FLOW OF LAVA FROM THE VOLCANO OF SAN SALVADOR, COVERING THE RAILROAD LINE, ERUPTION OF 1917.

Photograph from Pan American Union.

1. WATERFALL AND BASALTIC FORMATION, DEPARTMENT OF LA LIBERTAD.

2. CLIFFS ALONG THE COAST, DEPARTMENT OF LA LIBERTAD.

Photographs from Dr. V. M. Huezo.

1. PRESS USED FOR EXTRACTING BALSAM.

2. BRACKISH LAGOON, DEPARTMENT OF LA LIBERTAD.

Photographs from Dr. V. M. Huezo.

1. WILD FIG TREE IN THE COASTAL REGION, SHOWING BUTTRESSES.

2. TAPPING BALSAM TREES.

Photographs from Dr. V. M. Huezo.

PLANTATION OF MAGUEY (AGAVE SP.). THE FIBER IS MUCH USED FOR MAKING ROPE.

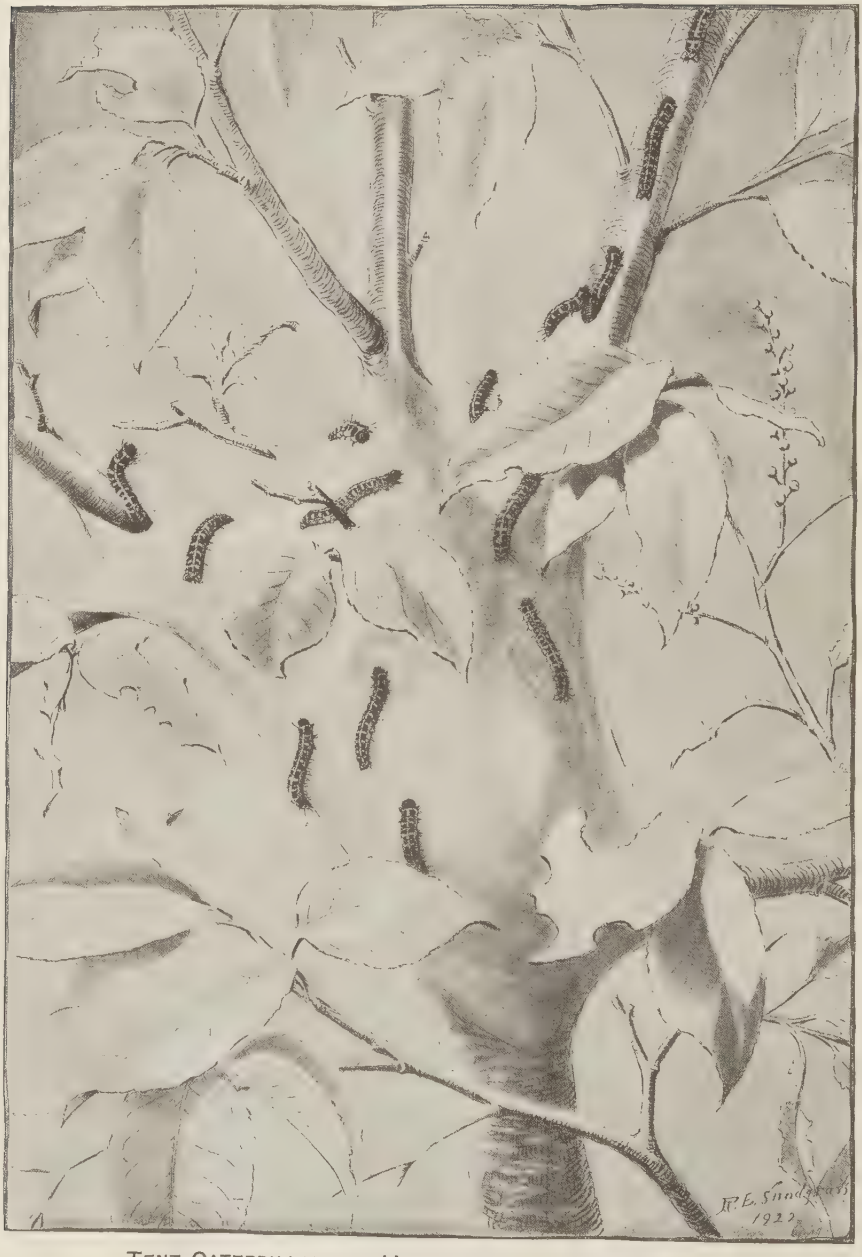
Photograph from Pan American Union.

AMATE (FICUS SP.) TREE IN A COFFEE PLANTATION NEAR SAN SALVADOR.

Photograph from Pan American Union.

FRUIT OF THE PEPINO (SOLANUM MURICATUM). ABOUT NATURAL SIZE.

Photograph from Dr. Salvador Calderón.



TENT CATERPILLARS AT HOME IN A WILD CHERRY TREE.

THE TENT CATERPILLAR.

By R. E. Snodgrass.
Office of Fruit Insect Investigations, Bureau of Entomology.

[With 1 plate.]

THE LIFE OF THE CATERPILLAR.

It is one of those bleak days of early spring that so often follow a period of warmth and sunshine, when living things seem led to believe the fine weather has come to stay.

Out in the woods a band of little caterpillars is clinging to the surface of what appears to be an oval swelling near the end of a twig on a wild cherry tree (fig. 1). The tiny creatures, scarce the tenth of an inch in length, sit motionless, benumbed by the cold, many with bodies bent into half circles as if too nearly frozen to straighten out. Probably, however, they are all unconscious and suffering nothing. Yet, if they were capable of it, they would be wondering what fate brought them into such a forbidding world.

Fig. 1.—Young tent caterpillars just hatched from an egg mass on a twig (1½ times natural size).

But fate in this case was disguised most likely in the warmth of yesterday, which induced the caterpillars to leave the eggs in which they had safely passed the winter. The empty shells are inside the spindle-shaped thing that looks so like a swelling of the twig, for, in fact, this is merely a protective covering over a mass of eggs glued fast to the bark. The surface of the covering is perforated by many little holes from which the caterpillars emerged, and is swathed in a network of fine silk threads which the caterpillars spun over it to give themselves a surer footing and one they might cling to unconsciously in the event of adverse weather, such as that which makes them helpless now. When nature designs any creature to live under trying circumstances she grants it some safeguard against destruction.

The web-spinning habit is one which, as we shall see, these caterpillars will develop to a much greater extent later in their lives, for our little acquaintances are young tent caterpillars. They are found most often, amongst woodland trees, on the choke cherry and wild black cherry. But they frequently infest apple trees in the orchards, and for this reason their species has been named the Apple-tree Tent Caterpillar, to distinguish it from related forms that do not commonly inhabit cultivated fruit trees. The scientific name is *Malacosoma americana.*

The egg masses are not hard to find at this season. They are generally placed near the tips of the twigs, which they appear to surround, and being of the same brownish color as the bark they look like swollen parts of the twigs themselves (fig. 2, A). Most of them are five-eighths to seven-eighths of an inch in length and almost half of this in width, but they vary in thickness with the diameter of the twig. A closer inspection shows that the mass really clasps the twig, or incloses it like a thick jacket lapped clear around. In form the masses are usually symmetrical, tapering at each end, but some are of irregular shapes, and those that have been placed at a forking or against a bud have one end enlarged.

The greater part of an egg mass consists of the covering material, which is a brittle, filmy substance like dry mucilage. Some of it is often broken away, and sometimes the tops of the eggs are entirely bare. The eggs are placed in a single layer next the bark (fig. 2, B), and there are usually 300 or 400 of them. They look like little, pale gray porcelain jars packed closely together and glued to the twig by their rounded and somewhat compressed lower ends. The tops are flat or a little convex. Each is the twenty-fourth of an inch in height, about two thirds of this in width, and has a capacity of one caterpillar. The covering is usually half again as deep as the height of the eggs, but varies in thickness in different specimens. The outer surface is smooth and polished, but the interior is full of irregular, many-sided air spaces, separated from one another by thin, filmy partitions (fig. 2, B).

Wherever the covering has been broken away, the bases of the partition walls leave brown lines that look like cords strapped and tied into an irregular net over the eggs (B), as if for double security against insurrection on the part of the inmates. But neither shells nor fastenings will offer effective resistance to the little thieves when they are taken with the urge for freedom. Each is provided with efficient cutting instruments in the form of sharp-toothed jaws that will enable it to open a round hole through the roof of its cell (fig. 2, C). The superstructure is then easily penetrated, and the emerging caterpillar finds itself on the surface of its former prison, along with its several hundred brothers and sisters, when all are out.

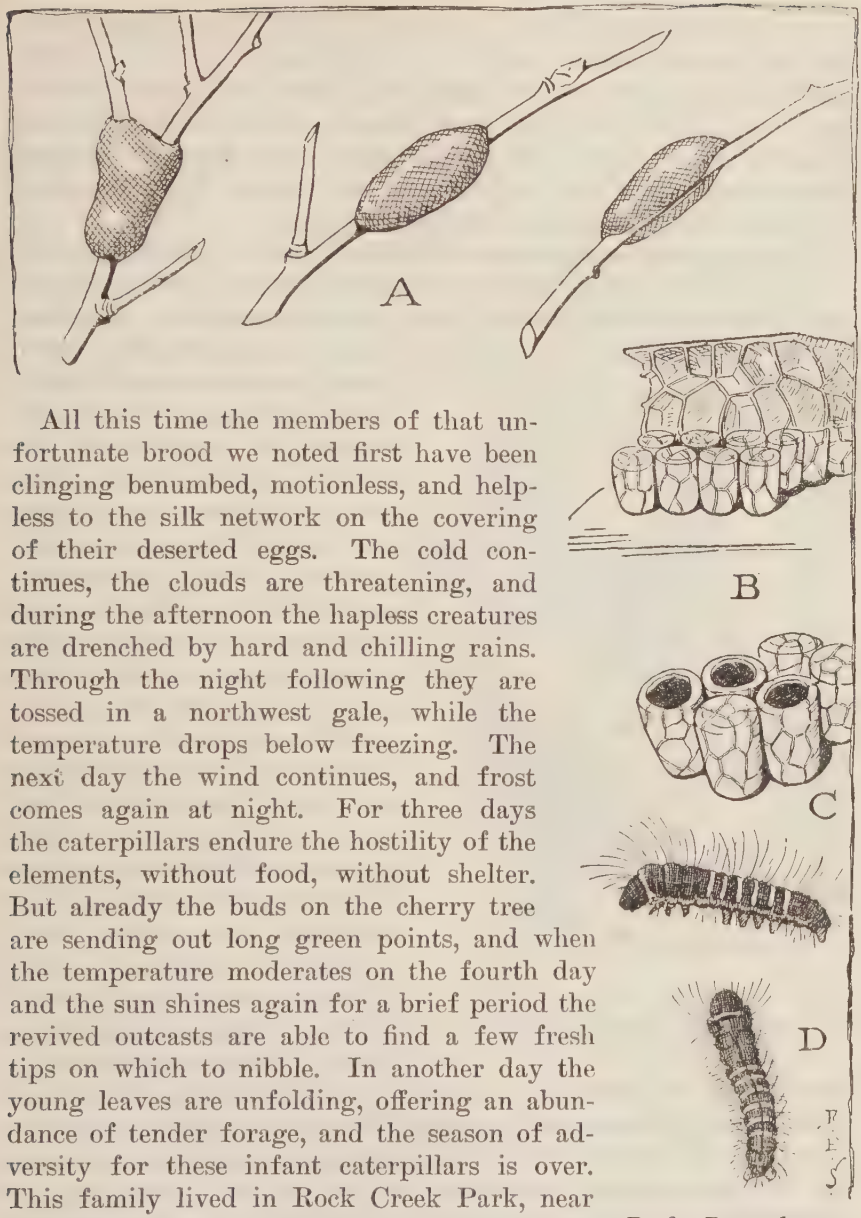


FIG. 2.—Eggs and young caterpillars. A, Egg masses on twigs (natural size); B, eggs exposed beneath the covering; C, several eggs more enlarged, three with holes in tops from which caterpillars emerged; D, newly hatched caterpillars (enlarged 10 times).

All this time the members of that unfortunate brood we noted first have been clinging benumbed, motionless, and helpless to the silk network on the covering of their deserted eggs. The cold continues, the clouds are threatening, and during the afternoon the hapless creatures are drenched by hard and chilling rains. Through the night following they are tossed in a northwest gale, while the temperature drops below freezing. The next day the wind continues, and frost comes again at night. For three days the caterpillars endure the hostility of the elements, without food, without shelter. But already the buds on the cherry tree are sending out long green points, and when the temperature moderates on the fourth day and the sun shines again for a brief period the revived outcasts are able to find a few fresh tips on which to nibble. In another day the young leaves are unfolding, offering an abundance of tender forage, and the season of adversity for these infant caterpillars is over. This family lived in Rock Creek Park, near Washington, D. C., in 1919, where it was hatched the 25th of March.

The newly hatched caterpillars are about one-tenth of an inch in length. The body is widest through the first segment and tapers somewhat towards the other end. The general color is blackish, but there is a pale gray collar on the first segment back of the head and a

grayish line along the sides of the body. Most of the segments have pale rear margins above, which are often bright yellow or orange on the fourth to the seventh segments. There is usually a darker line along the middle of the back. The body is covered with long gray hairs, those on the sides spreading outward, those on the back curving forward. After a few days of feeding the caterpillars increase to nearly twice their length at hatching.

When the weather continues fair after the time of hatching the caterpillars begin their lives with happier days, and their early history is different from that of those unfortunates above described. Three other broods, which were found hatching in Rock Creek Park on March 22, before the period of bad weather had begun, were brought indoors and reared under more favorable circumstances. These caterpillars spent but little time on the egg masses and wasted only a few strands of silk upon them. They were soon off on exploring expeditions, small processions going outward on the twigs leading from the eggs or their vicinity, while some individuals dropped at the ends of threads to see what might be below. Most, however, at first went upward as if they knew the opening leaf buds should lie in that direction. If this course, though, happened to lead them up a barren spur, a squirming, furry mob would collect on the summit, apparently bewildered by the trick their instinct played upon them. On the other hand, many followed those that first dropped down on threads, these in turn adding other strands till soon a silken stairway was constructed on which individuals or masses of little woolly bodies dangled and twisted as if either enjoying the sport or too fearful to go farther.

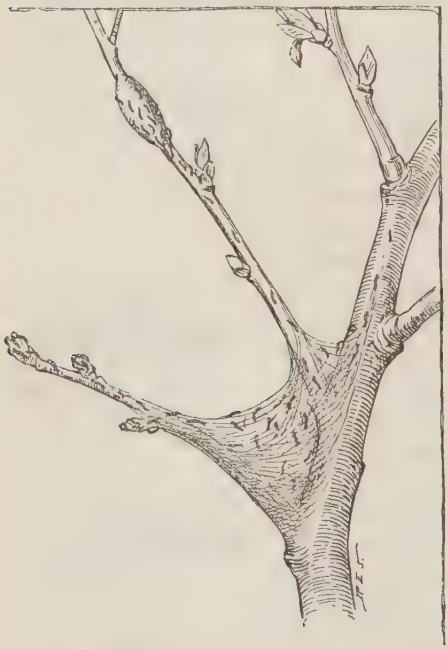


FIG. 3.—First tent made by young caterpillars (about half natural size).

For several days these young caterpillars led this happy, irresponsible life, exploring twigs, feeding wherever an open leaf bud was encountered, dangling in loose webs, but spinning threads everywhere. Yet, in each brood, the individuals kept within reach of one another, and the trails of silk leading back to the main branch al-

ways insured the possibility of a family reunion whenever this should be desired.

One morning, the 27th, one family had gathered in its scattered members and these had already spun a little tentlike web in the crotch between the main stem of the supporting twig and two small branches (fig. 3). Some were crawling on the surface of the tent, others were resting within, still others were traveling back and forth on the silk trails leading outward on the branches, and the rest were massed about the buds devouring the young leaves. The establishment of the tent marks the beginning of a change in the caterpillars' lives; it entails responsibilities that demand a fixed course of daily living. In the lives of the tent caterpillars this point is what the beginning of school days is to us—the end of irresponsible freedom and the beginning of subjugation to conventional routine.

FIG. 4.—Young caterpillars matted on a flat sheet of web (about natural size).

Every tent caterpillar family that survives infancy eventually reaches the point where it begins the construction of a tent, but the early days are not always spent alike, even under similar circumstances, nor is the tent always begun in the same manner.

At Wallingford, Conn., where the season for both plants and insects is much later than in the latitude of Washington, three broods of tent caterpillars were found hatching on April 8 of this same year. These also met with dull and chilly weather that kept them huddled on their egg coverings for several days. After four days the temperature moderated sufficiently to allow the caterpillars to move about a little on the twigs, but none were seen feeding till the 14th—six days after the hatching. Yet they had increased in size to about one-eighth of an inch in length.

Wherever these caterpillars camped in their wanderings over the small apple trees they inhabited they spun a carpet of silk to rest upon, and there the whole family collected in such a crowded mass that it looked like a round, furry mat (fig. 4). The carpets afforded the sleepers a much safer bed than the bare, wet bark of the tree, for if the sleepers should become stupefied by cold the claws of their feet would mechanically hold them fast to the silk during the period of their helplessness. The test came on the 16th and the night fol-

lowing, when the campers were soaked by hard, cold rains till they became so inert they seemed reduced to lifeless masses of soggy wool. On the afternoon of the 17th the temperature moderated, the sun came out a few times, the wetness evaporated from the trees, and most of the caterpillars revived sufficiently to move about a little and dry their fur. Though a few had been washed off the carpets by the violence of the storm and perished on the ground, and in one camp about 20 dead were left behind on the web, the majority had survived.

For several days after this, during better weather, the caterpillars of these families continued their free existence, feeding at large on the opening buds, but returning during resting periods to the webs or constructing new ones at more convenient places. Often each family split into several bands, each with its own retreat, yet all remained in communication by means of the silk trails the caterpillars left wherever they went.

The camping sites were either against the surface of a branch or in the hollow of a crotch. Though the carpetlike webs stretched over these places were spun apparently only to give secure footing, those at the crotches often roofed over a space well protected beneath, and frequently many of the caterpillars crawled into these spaces to avail themselves of their shelter. Yet for 12 days none of the broods constructed webs designed for coverings. Then, on the morning of the 20th, one family was found to have spun several sheets of silk above the carpet on which its members had rested for a week and all were now inside their first tent. These caterpillars were nearing the end of their first stage, and two days later the first molted skins were found in the tent, 14 days after the date of hatching.

In Stage II the caterpillars have a new color pattern and one which begins to suggest that characteristic of the species in its more mature stages (fig. 6). On the upper part of the sides the dark color is broken into a series of quadrate spots, each spot partially split lengthwise by a light streak, and the whole series on each side is bordered above and below by distinct pale lines, the upper line often yellowish. Below the lower line there is a dark band, and below this another pale line just above the bases of the legs. The back of the first body segment has a brown transverse shield, and the last three segments are continuously brown, without distinction of spots or lines.

From now on the tents increase rapidly in size by successive additions of web spun over the tops and sides, each new sheet covering a flat space between itself and the last. The old roofs thus become successively the floors of the new stories. The latter, of course, lap over on the sides, and many continue clear around and beneath the

original structure; but since the tent was started in a crotch, the principal growth is upward with a continual expansion at the top. During the building period a symmetrical tent is really a beautiful object. (Pl. I.) Half hidden amongst the leaves, its silvery whiteness pleasingly contrasts with the green of the foliage, its smooth silk walls glisten where the sun falls upon them and reflect warm grays and purples from their shadows.

The caterpillars have adopted now a community form of living—they all feed together, they all rest and digest at the same time, they all work at the same time, and their days are divided into definite periods for each of their several duties. There is, however, no visible system of government or regulation, but with caterpillars acts are probably functions; that is, the urge probably comes from some physiological process going on within them which may be influenced somewhat by the weather.

The activities of the day begin with breakfast. Early in the morning the family assembles on the tent roof, and then, about 6.30, proceeds outward in one or several orderly columns on the branches. The leaves on the terminal twigs furnish the material for the meal. After two hours or more of feeding appetites are appeased, and the caterpillars go back to the surface of the tent, usually by 8.30 or 9 o'clock. Here they do a little spinning on its walls, but no strenuous work is attempted at this time, and generally within half an hour the entire family is reassembled inside the tent. Most frequently the crowd collects first in the shady side of the outermost story, but as the morning advances the caterpillars seek the cooler inner chambers, where they remain hidden from view.

In the early part of the afternoon a light lunch is taken. The usual hour is 1 o'clock, but there is no set time. Occasionally the participants appear shortly after 11, sometimes at noon, and again not till 2 or 3 o'clock, and rarely as late as 4. As they assemble on the roof of the tent they spin and weave again till all are ready to proceed to the feeding grounds. This meal lasts about an hour. When the caterpillars return to the tent they do a little more spinning before they retire for the afternoon siesta. Luncheon is not always fully attended and is more popular with caterpillars in the younger stages, being dispensed with entirely, as we shall see, in the last stage.

Dinner, in the evening, is the principal meal of the day, and again there is much variation in the time of service. Daily observations made on five colonies at Wallingford, Conn., during 1922, from the 8th to the 26th of May, gave 6.30 p. m. as the earliest record for the start of the evening feeding and 9 o'clock as the latest, but the dinner hour is preceded by a great activity of the prospective diners assembled on the outside of the tents. Though the energy of the tent

caterpillars is never excessive, it appears to reach its highest expression at this time. The tent roofs are covered with restless throngs, most of the individuals busily occupied with the weaving of new web, working apparently in desperate haste as if a certain task had been set for them to finish before they should be allowed to eat. Possibly, though, the stimulus comes merely from a congestion of the silk reservoirs in their bodies, and the spinning of the thread affords relief.

The tent caterpillar does not weave its web in regular loops of thread laid on by a methodical swinging of the head from side to side, which is the method of most caterpillars. It bends the entire body to one side, attaches the thread as far back as it can reach, then runs forward a few paces and repeats the movement, sometimes on the same side, sometimes on the other. The direction in which the thread is carried, however, is a haphazard one, depending on the obstruction the spinner meets from others working in the same manner.

But amongst the crowd of weavers there are always some that are not working, though they are just as active. These are running back and forth over the surface of the tent like boarders impatiently waiting the sound of the dinner bell. Perhaps they are individuals that have finished their work by exhausting their supply of silk.

At last the signal for dinner is sounded. It is heard by the caterpillar, though it is not audible to an outsider. A few respond at first and start off on one of the branches leading from the tent. Others follow, and presently a column is marching outward, usually keeping to the well-marked paths of silk till the distant branches are reached. Here the line breaks up into several sections which spread out over the foliage. The tent is soon deserted. For one, two, or three hours the repast continues, the diners often returning home late at night. Observations indicate that this is the regular habit of the tent caterpillar in its earlier stages, and perhaps up to the sixth or last stage of its life. The writer noted entire colonies back in the tent for the night in at least nine instances at hours ranging from 9 to 11 p. m. In other cases a part of the crowd was still feeding when last observed; but daylight-saving time was then in vogue and 11 o'clock was doing duty for midnight. The observations are recorded in standard time.

In describing the life of a community of insects it is seldom possible to make general statements that will apply to all the individuals. The best that a writer can do is to say what he sees most of the insects do, for, as in other communities, there are always those eccentric members who will not conform with the customs of the majority. Occasionally a solitary tent caterpillar may be seen feed-

ing between regular meal times. Often one works alone on the tent, spinning and weaving long after its companions have quit and gone below for the midday rest. Such a one appears to be afflicted with an overdeveloped sense of responsibility, and looks as foolish as those human individuals who must always put everyone else to shame

FIG. 5.—Caterpillars feeding at night.

about the camp by fussing around over unnecessary work when the rest of the crowd is lying around trying to enjoy an afternoon snooze. Then, too, there is nearly always one amongst the group in the tent who can not get to sleep. He flops this way and that, striking his companions on either side and keeping them awake also. These are annoyed, but they do not retaliate, because they seem to realize that

their restless comrade has but a common caterpillar affliction and must be endured.

Many of these little traits make the caterpillars seem almost human. But, of course, this is just a popular form of expression. In fact, it is too popular—we take too much satisfaction in referring to our faults as particularly human characteristics. What we really should say is not how much tent caterpillars are like us in their shortcomings, but how much we are still like tent caterpillars. We both revert more or less in our instincts to times before we lived in communities, to times when our ancestors lived as individuals irresponsible one to another.

The tent caterpillars ordinarily shed their skins six times during their lives. At each molt the skin splits along the middle of the back on the first three body segments and around the back of the head. It is then pushed off over the rear end of the body, usually in one piece, though most other caterpillars cast off the head covering separate from the skin of the body in all molts but the last. The molting takes place in the tent and renders the caterpillars inactive for the greater part of two days. When most of them molt at the same time there results an abrupt cessation of activity in the colony. By the time the caterpillars reach maturity the discarded skins in a tent outnumber the caterpillars 5 to 1.

The first stage of the caterpillars, as already described (fig. 2, D), suggests nothing of the color pattern of the later stages, but in Stage II the spots and stripes of the mature caterpillars begin to be formed. In succeeding stages the characters become more and more like those of the sixth or last stage (fig. 6), when the colors are most intensified and their pattern best defined. Particularly striking now are the velvety black head with the gray collar behind, the black shield of the first segment split with a median zone of brown, the white stripe down the middle of of the back, the large black lateral blotches, each inclosing a spot of silvery bluish white, the distinctly bluish color between and below the blotches, and the hump on the eleventh segment, where the median white line is almost obliterated by the crowding of the black from the sides. Yet the creatures wearing all this lavishness of decoration make no ostentatious show, for the colors are all nicely subdued beneath the long reddish brown hairs that clothe the body.

In the last stage the average full-grown caterpillar is about 2 inches long, but some reach a length of $2\frac{1}{2}$ inches when fully stretched out. The head measures 3 to $3\frac{1}{2}$ millimeters wide in this stage, or a little more than one-eighth inch. In Stage V the largest heads are not wider than $2\frac{1}{2}$ millimeters; in Stage IV they do not exceed $1\frac{1}{2}$ millimeters; in III, 1 millimeter; in II, about two-thirds

millimeter; and in I, one-half millimeter. The width of the head is a better index to the stage than is the length of the body.

In southern Connecticut the tent caterpillars begin to go into their sixth and last stage about the middle of May. They now change their habits in many ways, disregarding the conventionalities and refusing the responsibilities that bound them in their earlier stages. They do little, if any, spinning on the tent, not even keeping it in decent repair. They stay out all night to feed, unless adverse weather interferes, thus merging dinner into breakfast in one long nocturnal repast. This is attested by observations made through most of several nights, when the caterpillars of four colonies which went out at the usual time in the evenings were found feeding till at least 4 o'clock the following mornings, but were always back in the tents at 7.30. When the caterpillars begin these all-night banquets, however, they dispense with the midday lunch, their crops being so crammed with food by morning that the entire day is required for its digestion. Some other writers have described the tent caterpillars as nocturnal feeders, and some have said they feed three times a day. Both statements, it now appears, are correct, but the writers have not noted that the two habits pertain to different periods of the caterpillar's history.

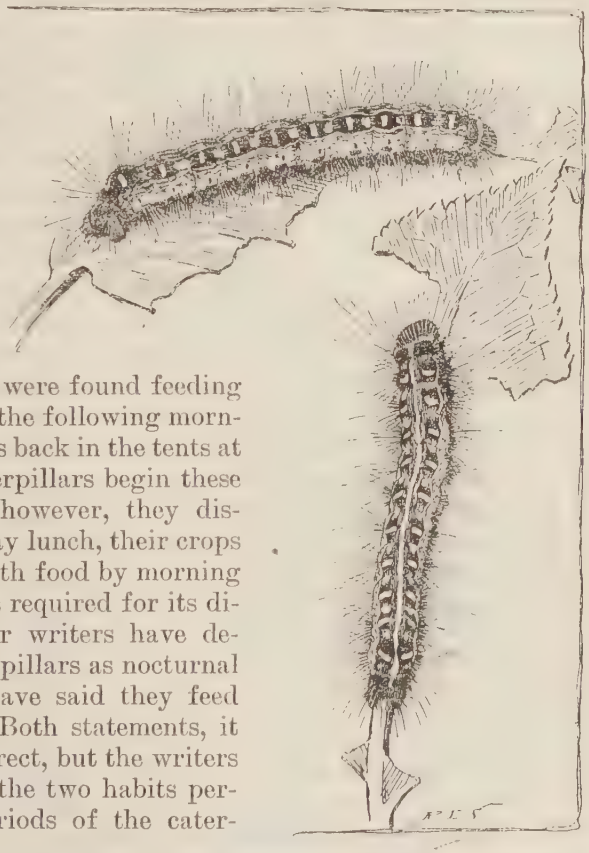


FIG. 6.—Mature tent caterpillars (natural size).

At any time during the caterpillars' lives adverse weather conditions may upset their daily routine. For two weeks, during May, days and nights had been fair and generally warm, but on the 17th the temperature did not get above 65° F., and in the afternoon threatening clouds covered the sky. In the evening light rains fell, but the caterpillars of the five colonies under observation came out as usual for dinner and were still feeding when last observed at 9 p. m. Rains continued through the night, however, and the temperature stood almost stationary between 50° and 55°.

The next morning three of the small trees containing the colonies were festooned with water-soaked caterpillars, all hanging motionless from leaves, petioles, and twigs, benumbed with exposure and incapable of action—more miserable-looking insects could not be imagined. No instinct of protection, apparently, had prevailed over their appetites, till, at last, overcome by wet and cold, they were saved only by some impulse that led them to grasp the support so firmly with the abdominal feet that they hung there mechanically when senses and power of movement were gone. Some hung by the hindmost pair of feet only, others grasped the support with all the abdominal feet. One colony and most of another were safely housed in their tents. These had evidently retreated before helplessness overtook them.

FIG. 7.—Twigs of choke cherry and apple denuded by tent caterpillars.

By 8 o'clock in the morning many of the suspended caterpillars were sufficiently revived to resume activity. Some fed a little, others crawled feebly toward the tents. By 9.45 most were on their way home, and at 10.45 all were under shelter.

Gentle rains fell during most of the day, but the temperature gradually rose to a maximum of 65°. Only a few caterpillars from the youngest colony came out to feed at noon. In the evening there was a hard, drenching rain, after which several caterpillars from two of the tents appeared for dinner. The next morning, the 19th, the temperature dropped to 49°, light rains continued, and not a caterpillar from any colony ventured out for breakfast. It looked as if they had learned their lesson, but it is more probable they were simply too cold and stiff to leave the tents. In the afternoon the sky cleared, the temperature rose, and the colonies resumed their normal life. The tent caterpillars' mode of feeding is to devour the leaves

clear down to the midribs (figs. 5 and 6), and in this fashion they denude whole branches of the trees they inhabit (fig. 7). While the wild cherry is the tree most preferred by the caterpillars, and the one on which the moths usually deposit their eggs, they also infest apple trees to a sufficient extent to make them a considerable pest in orchards. They are easily poisoned on trees sprayed with arsenicals. In others the best remedy is to clean the tents out with a brush when the caterpillars are in them and then to kill the caterpillars before they escape. Occasionally the tents are found in other trees, and have been recorded from cultivated cherry, plum, peach, rose, witch-hazel, beech, barberry, oaks, willows, poplars, and birch.

Since the caterpillars have big appetites it sometimes happens that a large colony in a small tree or several colonies in the same tree strip the tree bare before they reach maturity. Clarence M. Weed says that in such cases the caterpillars descend to the ground and search for some other tree on which they can feed. (Bull. 38, N. H. Ag. Exp. Station.) The writer never saw a colony reduced to this extremity by its own feeding, but produced similar conditions for one in a small apple tree by removing all the leaves. This was on May 19, and the caterpillars were mostly in their fifth stage.

At 7 o'clock in the evening the caterpillars in this colony came out as usual, and, after doing the customary spinning on the tent, started off to get their dinner, suspecting nothing till they came to the cut-off ends of the branches. Then they were clearly bewildered—they returned and tried the course over again, they tried another branch, all the other branches; but all ended alike in bare stumps. Yet, there were the accustomed trails, and their instincts clearly said that following silk paths led to food. So all night the caterpillars hunted for the missing leaves; they went over and over the same courses, but none ventured below the upper part of the trunk. By 3.45 in the morning many had given up and had gone back to the tent, but the rest continued the hopeless search. At 7.30 a few bold explorers had discovered some remnants of water sprouts at the base of the tree and fed there till 10 o'clock. At 11 all were back in the tent.

At 2 o'clock in the afternoon the crowd was out again and a mass meeting was being held at the base of the tree. But nobody seemed to have any idea of what to do, and no leader rose to the occasion. A few cautious scouts were making investigations over the ground to the extent of a foot or a little more from the base of the trunk, but, though there were small apple trees on three sides 5 feet away, only one small caterpillar ventured off toward one of these. He, however, missed the mark by 12 inches and continued onward, but probably chance eventually rewarded him. At 3 p. m. the meeting

broke up and the members went home. They were not seen again that evening or the next morning.

During this day, the 21st, and the next an occasional caterpillar came out of the tent but soon returned, and it was not till the evening of the 22d that a large number appeared. These once more explored the naked branches and traveled up and down the new paths on the trunk, but none was observed to leave the tree. On the 23d and 24th no caterpillars were seen. On the 25th the tent was opened and only two small individuals were found within it. Each of these was weak and flabby, its alimentary canal completely empty, its fat tissue almost gone. But what had become of the rest? Probably they had wandered off unobserved one by one. Certainly there had been no organized migration. Solitary caterpillars were subsequently found on a dozen or more small apple trees in the immediate vicinity. It is likely that most of these had molted and had gone into the last stage, since their time was ripe. But this was not determined.

In general, the tent caterpillars live easy and comfortable lives. Still, they have their troubles, some of them serious ones. They are destroyed when young by exposure to adverse weather, they are eaten by birds and by other insects, they are killed by internal parasites, and they are attacked by a deadly disease. But insects seldom actively contend against destructive forces. They do not believe in direct action. They are like plants in this respect, depending rather on numbers than on resistance for the maintenance of their species.

Yet even the tent caterpillars sometimes make feeble efforts at self-defense. Amongst their enemies is a small bug which lies in wait for them as they come out to feed. The bug is armed with a large piercing and sucking beak, and when it sees a column of caterpillars headed in its direction it cautiously advances and stabs at a passing individual. If the threatened caterpillar is not punctured, it wards off other strokes from the bug by suddenly switching its body from side to side and goes on its way unharmed. The intimidated bug often has to make many assaults on members of the procession before it secures a victim, which, according to the custom of its species, must be speared in the second body segment. When at last, though, its thrust takes hold the assassin lifts the kicking and squirming victim off its feet and lets it hang free from the end of its beak. Then, crooking the elbow of the four-jointed sheath of the beak and holding the slender piercing and tubular parts firmly in the tip, the bug sucks out the juices of the writhing caterpillar as calmly as if it were drinking a glass of soda through a straw (fig. 8). But the caterpillar shortly ceases its motions and hangs limp, as if the bug had injected some anesthetic into its body. Several species of these bugs (*Podisus*) attack the caterpillars also in the tents.

While many of the caterpillars protect themselves from the attack of predaceous insects and ward off parasitic flies by their sudden swinging of the body from side to side, they frequently make the same motions for no evident reason. We have noted how one may begin switching in the tent, perhaps fighting imaginary enemies in his dreams, much to the annoyance of his companions. The tent caterpillars, however, never exhibit the concert wagging characteristic of the fall webworms. (See p. 402, Smithsonian Report for 1921.)

A number of small and minute beetles live in the tents of the tent caterpillar, but these probably only feed there on the accumulated refuse. They are to be compared with the mice and rats of human dwellings.

After the caterpillars go over into their last stage the tents are neglected and rapidly fall into a state of dilapidation. Birds often poke holes in them with their bills, and they rip off sheets of silk which they carry away for nest-building purposes. The caterpillars do not even repair these damages. The rooms of the tent become filled with accumulations of frass, molted skins, and the shriveled bodies of dead caterpillars. The walls are discolored by rains which beat into the openings and soak through the refuse. Thus, what were shapely objects of glistening silk are transmuted into formless masses of dirty rags.

FIG. 8.—A bug (*Podisus maculiventris*) feeding on a caterpillar hanging from its beak.

But the caterpillars, now in their finest dress, are oblivious of their sordid surroundings and sleep all day amidst these disgusting and apparently insanitary conditions. However, the life in the tents will soon be over, so it appears that the caterpillars simply think, "What's the use?" But, of course, caterpillars do not think; they arrive at results by instinct, in this case by the lack of an instinct, for they have no impulse to keep the tents clean or in repair when doing so would be energy wasted. Nature demands a practical reason for most things.

The tent life continues about a week after the last moth, and then the family begins to break up, the members leaving singly or in bands, but always as individuals without further concern for one another. Judging from their previous methodical habits, one would suppose that the caterpillars starting off on their journeys would

simply go down the trunks of the trees and walk away. But no; once in their lives they must have a dramatic moment. A caterpillar comes rushing out of a tent as if suddenly awakened from some terrible dream or as if pursued by a demon, hurries outward along a branch, goes to the end of a spur or the tip of a leaf, and without slackening continues out into space till the end of the support tickles his stomach, when suddenly he gives a flip into the air, turns a somersault, and lands on the ground. (Fig. 9.)

The first performance of this sort was observed on May 15. On the afternoon of the 19th, 20 or more caterpillars from two neighboring colonies were seen leaving the trees in the same fashion within half an hour. Most of the members of one of these colonies had their last molt on May 12 and 13. During the next few days other caterpillars were observed jumping from four trees containing colonies under observation. All of these went off individually at various times, but most of them early in the afternoon. Many caterpillars simply drop off when they reach the end of the branch, without the acrobatic touch, but only three were seen to go down the trunk of a tree in commonplace style.

FIG. 9.—A tent caterpillar in the last stage leaving the tree by jumping from the end of a twig to the ground.

The population of the tents gradually decreases during several days following the time when the first caterpillar departs. One of the two tents from which the general exodus was noted on May 19 was opened on the 21st and was found to contain only one remaining caterpillar. On the evening of the 22d a solitary individual was out feeding from the other tent. The two younger colonies maintained their numbers till the 22d, after which they diminished till, within a few days, they too were deserted. The members of all these colonies hatched from the eggs on April 8, 9, and 10, so seven weeks is the greatest length of time that any of them spent on the trees of their birth. The caterpillar that left the tent on the 15th came from a colony that began to hatch on April 10, giving an observed minimum of 36 days.

As soon as a departing caterpillar lands on the ground it sets off at a rapid pace as if it had already picked out its destination and knew what road to take. Early in the afternoon of May 21 a caterpillar was observed making its headlong rush from the tent of one of the later colonies. It jumped from the southeast side of the tree and, without hesitation, started off at a running gait in the same direction. Its course took it first across a narrow strip of grass, then

diagonally over a bare garden plot that had been plowed and harrowed, but beaten down fairly smooth and solid by recent rains, except where it had since been raked. The traveler proceeded over smooth ground and over raked ground, changing his course for nothing, being neither deterred nor deflected by any obstacle on the road. He climbed over stones and rough clods, dodged between the leaf stems of occasional plantains that stood in the path, and threaded his way through labyrinths of upturned roots, but always held the course to the southeast. For 70 feet there was not a deviation of more than 2 feet on either side of a straight line. Yet there was no prominent mark ahead; the sun was a little west of south and a high board fence on the east side of the yard crossed the line of the course at an angle of 45°. Neither sun nor fence, therefore, appeared to be the objective; so, it seems that the traveler must have secretly carried a compass somewhere on his person. At the end of 70 feet he abruptly veered a little to the south and headed now directly toward a large apple tree not far distant. When 12 feet from the trunk he was lost to sight in some tall grass and weeds growing at the edge of the garden. Up to this point the caterpillar had covered just 100 feet and had made the journey in 34 minutes.

Half an hour later the trunk of the tree, which was banded with tanglefoot 4 feet from the ground, was examined to see if any traveling caterpillar had arrived. None was on the trunk, but four were sitting quietly on the stems of water sprouts beside it. In the evening of the same day nine caterpillars were feeding on the leaves of these sprouts and one was crawling up the tree. On the next evening there were 12 in all. Evidently here was a rendezvous.

This tree stood at the corner of a small orchard of large apple trees, the trunks of all of which were circled with tanglefoot. Water sprouts were abundant through the orchard, but only two caterpillars were found elsewhere than on those by the corner tree. Yet the latter was not the nearest tree to the tents—the trees directly south could have been reached by a shorter course, while the plot of small trees containing the tents offered an abundance of forage close at hand. No tents were to be found in the orchard.

It is unfortunate that other caterpillars were not followed in their travels. But since many were found at this time scattered here and there on the small trees in the yard it is evident that their journeys had not taken them far. These quietly rested during the day on the twigs and fed on the leaves in the evening, and probably all night. The excitement and hurry of leaving the tents had been but a momentary spasm in their lives. Once on the new feeding ground their normal placid temperaments returned. The 12 caterpillars on the water sprouts lived there in the same quiet manner, but soon their

number began to decrease from day to day, till by the end of a week all had departed.

When the mature caterpillars disappear in this mysterious manner they go off to spin their cocoons, but those from our colonies hid themselves so effectively for this act that few of them were recovered. Two cocoons were found spun against the under side of a wooden bench a few feet from where the 12 caterpillars spent their last days on the water sprouts, and one in dry grass beneath. Several were found elsewhere spun vertically amongst blades of tall grass, one was taken from a mass of cobwebs on the floor of an unused chicken house, and another from the rafters of an open shed. It is usually stated that the tent caterpillar spins its cocoon "most anywhere" amongst grass and rubbish, on tree trunks, on fences, and on buildings. But Dr. B. A. Porter and the writer made a thorough search in the neighborhood of six tents in a small tree beside a country road without discovering the site of a single cocoon. We examined the surrounding tall grass and weeds, turned over rocks on the ground, carefully inspected a stone wall across the road, and examined the trunks and branches of near-by trees.

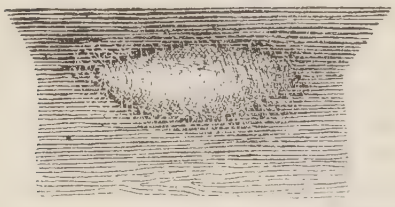


FIG. 10.—A tent caterpillar cocoon (natural size).

The caterpillars that left the two colonies in the yard on May 19 were captured and confined in an outdoor cage where they were daily supplied with fresh cherry leaves. All of these spun their cocoons in the cage between May 24 and 28, and from this we may infer that the caterpillars normally spend about a week in feeding after they leave the tents. Since most of those in the cage had molted last on the 12th or 13th, they were from 12 to 16 days in the last stage before spinning their cocoons.

The cocoon is a slender oval or almost spindle-shaped object, the larger ones being about an inch long and half an inch wide at the middle (fig. 10). The cocoon is spun of white silk thread, but its walls are stiffened and colored by a yellow substance infiltrated like starch all through the meshes of the web.

In building the cocoon the caterpillar first spins a loose network of threads at the place selected, and then, using this for a support, weaves about itself the walls of the final structure. On account of its large size, as compared with the size of the cocoon, the caterpillar is forced to double on itself to fit its self-imposed cell. Most of its hairs, however, are brushed off and become interlaced with the threads to form a part of the cocoon fabric. When the spinning is finished the caterpillar ejects a yellowish, pasty liquid from its intes-

tine, which it smears all over the inner surface of the case, but the substance spreads through the meshes of the silk, where it quickly dries and gives the starchy stiffness to the walls of the finished cocoon. It readily crumbles into a yellow powder, which becomes dusted all over the caterpillar within and floats off in a small yellow cloud whenever a cocoon is pulled loose from its attachments.

The cocoon is the last resting place of the caterpillar. If the caterpillar lives it will come out of its prison as a moth, leaving the garments of the worm behind. It may, however, be attacked by parasites that will shortly bring about its destruction. But even if it goes through the period of change successfully it must remain in the cocoon about three weeks. In the meantime it will be of interest to learn something of the structure of a caterpillar, the better to understand its physiology and some of the details of the process of its transformation.

THE STRUCTURE AND PHYSIOLOGY OF THE CATERPILLAR.

A caterpillar looks like a worm, but it is not a worm. It is a young moth that has carried the idea of independence of youth to an extreme degree, but which, instead of rising superior to its parents,

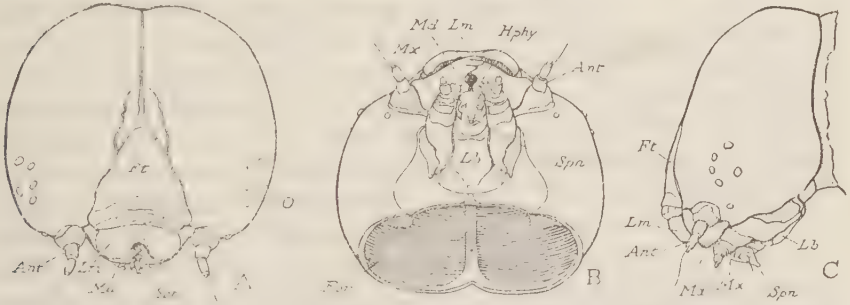


FIG. 11.—The head of a tent caterpillar. A, Facial view; B, under view; C, side view. *Ant*, antenna; *For*, opening of back of head into body; *Ft*, front; *Hphy*, hypopharynx; *Lb*, labium; *Lm*, labrum; *Md*, mandible; *Mx*, maxilla; *O*, eyes; *Spn*, spinneret.

has degenerated into the form of a worm. What an excellent theme this would furnish to those who at present are so bewailing what they believe to be a shocking tendency toward an excess of independence on the part of the young of the human species! But the moral aspect of the lesson loses its force when we learn that among insects this freedom of the caterpillar from parental restraint gives advantages to both young and adults, and, therefore, results in good to the species as a whole. Independence entails responsibilities. A creature that leaves the beaten paths of its ancestors must learn to take care of itself in the new way. And this the caterpillar has learned to do preeminently well, as it has come up the long road of evolution, till now it possesses both instincts and physical organs that make it one of the dominant forms of insect life.

The general external form and structure of a caterpillar may be learned from a study of Figure 17, A. But the external organs of chief interest are those of the head (fig. 11), including the mouth, the jaws, and the silk-spinning instrument. The facial view (A) shows the notched upper lip or *labrum* (*Lm*) suspended from the triangular frontal plate (*Ft*) like a protective flap over the bases of the jaws. The latter, called *mandibles* (*Md*), are large, heavy appendages at the sides of the mouth, swinging out and in on two ball-and-socket hinges. The muscles that move them are shown in Figure 12, A. The cutting edge of each mandible carries a number of strong teeth. At the sides of the jaws are the two small three-jointed *antennae* (fig. 11, *Ant*). The caterpillar has 12 very small eyes, one near the base of each antenna and the others in two groups of 5 each on the sides of the head (fig. 11, A, *O*). But with all its eyes the caterpillar appears to be very nearsighted and gives little evidence of being able to see more than the difference between light and darkness. Those tent caterpillars that were starving on the denuded tree failed to perceive other food trees in full leaf only a few feet away.

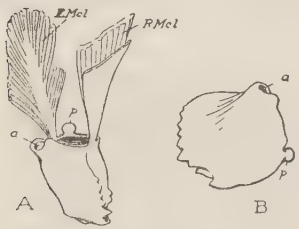


FIG. 12.—The mandibles or jaws of the caterpillar detached from the head. A, front view of right mandible; B, underside of the left. *a* and *p*, the socket and knob that hinge the jaw to the head; *EMcl* and *RMcl*, extensor and retractor muscles that move the jaw.

The large complex organ that projects behind or below the mouth like a thick under lip (fig. 11, C) is a combination of three parts that are separate in other insects. These are a second pair of soft jaws, called *maxillæ* (B, C, *Mx*), and the true under lip, or *labium* (*Lb*). The most important part of this combined structure in the caterpillar, however, is the hollow spine (A, B, C, *Spn*) pointed downward and backward from the end of the labium. This is the *spinneret*. From it issues the silk thread with which the caterpillar weaves its tent and its cocoon.

The fresh silk is a liquid formed in long tubular glands extending back in the body of the caterpillar to the tenth segment (fig. 13, A, *Gl*). The middle part of each tube is enlarged into a reservoir (*Res*), where the silk liquid may accumulate, and the first part consists of a narrow duct (*Dct*) which unites with the duct from the other gland in a thick-walled sac (*Pr*) that finally opens into the spinneret. Two small glands, which look like bunches of grapes (*GlF*), open into the ducts near their front ends.

The relation of the ducts and the sac to the spinneret is seen in the side view of the maxilla and labium shown at B in Figure 13.

The sac (*Pr*), into which the ducts of the silk gland opens, is called the *silk press*, because its thick walls are supposed to squeeze the silk into a thread varying in form and thickness according to the pressure exerted on it. The cut end of the press, given at E, shows the crescent form of its cavity (*Lum*) in cross section, and the thickening in its roof (*Rph*), called the *raphe*. Muscles (*Mcls*) inserted on the raphe and the sides of the press serve to enlarge the interior of the press by lifting the roof and spreading the walls. The four sets of these muscles are shown from above at C. The opening of the press cavity probably sucks the silk liquid into it from the reservoirs, and when the muscles relax the elastic roof springs back and forces the silk through the spinneret. The continuous passage from the ducts into the press and from the press into the spinneret is shown from the side at D.

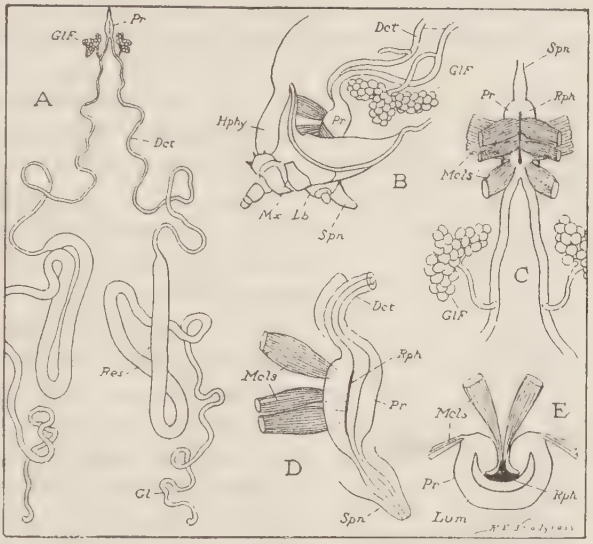


FIG. 13.—The silk glands and spinning organs. A, the silk glands (*Gl*), their reservoirs (*Res*), and ducts (*Dct*) opening into the silk press (*Pr*). *Glf*, glands of Filippi opening into the ducts.

B, side view of maxilla (*Mx*) and tip of labium (*Lb*) carrying the spinneret (*Spn*) showing the silk press (*Pr*) in place and the ducts (*Dct*) entering it.

C, upper side of the silk press (*Pr*), showing the 4 sets of muscles (*Mcls*) inserted on its walls and on the rod-like raphe (*Rph*) in its roof.

D, side view of the press, ducts, spinneret, raphe, and muscles.

E, cross section of the press, showing its cavity or lumen (*Lum*), which is enlarged when the muscles lift up the collapsed roof.

The silk liquid is very gummy and adheres tightly to whatever it touches, while at the same time it hardens rapidly and becomes a tough, inelastic thread as it is drawn out of the spinneret when the caterpillar swings its head away from the point of attachment.

The mouth of the caterpillar is between the jaws and the lips. It opens into a short gullet or *œsophagus*, which is the first part of the alimentary canal (fig. 14, *Œ*). The rest of the canal is a wide tube occupying most of the space within the caterpillar's body and is divided into the *crop* (*Cr*), the stomach or *ventriculus* (*Vent*), and the *intestine* (*Int*). The crop is a sac for receiving the food

and varies in size according to the amount of food it contains (A and B, *Cr*). The stomach (*Vent*) is the largest part of the canal. Its walls are loose and wrinkled when it is empty, or smooth and tense when it is full. The intestine (*Int*) consists of three divisions, a short part just back of the stomach, a larger middle part, and a saclike end part called the *rectum* (*Rect*). Six long tubes (*Mal*) are wrapped in many coils about the intestine and run forward and back in long loops over the rear half of the stomach. The three on each side unite into a short basal tube, which opens into the first part of the intestine. The terminal parts of the tubes are coiled inside the muscular coat of the rectum. These tubes are known as the *Malpighian tubules.*

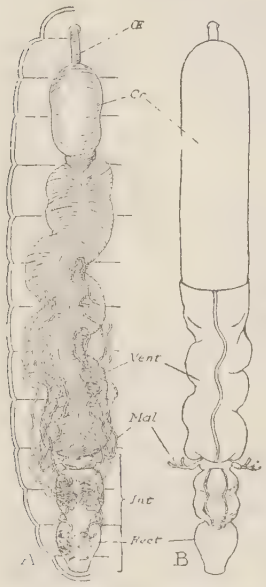


FIG. 14.—The alimentary canal of the caterpillar. A, before feeding; B, after feeding. *Cr*, crop; *Int*, intestine; *Mal*, Malpighian tubules; *OE*, oesophagus; *Vent*, stomach or ventriculus.

When a tent caterpillar goes out to feed the fore part of its body is soft and flabby; when it returns to the tent the same part is tight and firm. This is because the caterpillar carries its dinner home in its crop, digests it slowly while in the tent, and then goes out for more when the crop is empty. It is quite easy to tell by feeling a caterpillar whether it is hungry or not. The empty, contracted crop is a small bag contained in the first three segments of the body (fig. 14, A, *Cr*); but the full crop stretches out to a long cylinder like a sausage, filling the first six segments of the body (fig. 14, B), its rear end sunken into the stomach and its front end pressed against the back of the head.

The fresh food in the crop consists of a soft, pulpy mass of leaf fragments. As this is passed into the stomach the crop contracts and the stomach expands, and the caterpillar's center of gravity is shifted backward with the food burden. The food is digested in the stomach and the undigested part is passed on into the intestine. As the stomach becomes empty there accumulates in it a dark-brown liquid, probably the gastric juice, and it becomes inflated with bubbles of gas. When the caterpillar goes to its meals both crop and stomach are sometimes empty, but usually the stomach still contains some food besides an abundance of the brown liquid and numerous gas bubbles. The refuse that accumulates in the middle section of the intestine is subjected to pressure by the muscles of the intestinal wall, and is here molded into a pellet which retains the imprint of the constrictions and pouches of this part of the intestine,

and looks like a small mulberry when passed on into the rectum and finally extruded from the body.

The alimentary canal is a tube made of a single layer of cells extending through the body; but its outer surface, that toward the body cavity, is covered by a muscle layer of lengthwise and crosswise fibers which cause the movement of the food through the canal. The gullet and crop and the intestine are lined internally with a thin cuticle continuous with that covering the surface of the body, and these linings are shed with the body cuticle every time the caterpillar molts.

The Malpighian tubules (fig. 14, *Mal*) are the kidneys of insects; they are the excretory organs that remove from the blood the waste products containing nitrogen, and discharge them into the intestine along with the waste parts of the food from the stomach. Ordinarily the Malpighian tubules are of a whitish color, but just before the caterpillar is ready to spin its cocoon they become congested with a bright yellow substance. Under the microscope this is seen to consist of masses of square, oblong, and rod-shaped crystals (fig. 15). At this time the caterpillar has ceased to feed and the alimentary canal contains no food or food refuse. The intestine, however, becomes filled with the yellow mass from the Malpighian tubules; and this is the material with which the caterpillar plasters the walls of its cocoon, giving them the yellowish color and stiffened texture. The yellow powder of the cocoon, therefore, consists of the crystals from the Malpighian tubules.

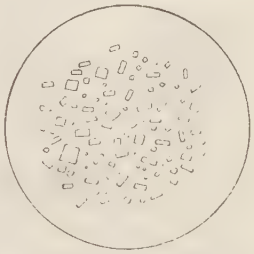


FIG. 15.—Crystals from the Malpighian tubules enjected into the walls of the cocoon.

We now come to the question of why the caterpillar eats so much. It is almost equivalent to asking, "Why is a caterpillar?" The caterpillar is the feeding stage in the insect's life—eating is its business, its reason for being a caterpillar. It eats not only to build up its own organs, many of which are to be broken down to furnish building material for those of the moth, but it eats also to store up within its body certain materials in excess of its own needs, which likewise will contribute to the growth of the moth.

The most abundant of the food reserves stored by the caterpillar is fat. With insects, however, fat does not accumulate amongst the muscles and beneath the skin. Insects never become "fat" in external appearance. Their fatty products are held in a special organ called the *fat body*.

In the tent caterpillar the fat body consists of a loose cellular network surrounding the crop and continued backward as a thin sheet.

adhering to the body wall through the region of the stomach. In a well-fed caterpillar the cells of the fat body (fig. 16, A) are full of small drops of a liquid that looks and acts like oil. Two physiological tests for fat are that it stains black in a weak solution of osmic acid and red in a solution called "Soudan III." The oily drops in the fat body of the tent caterpillar sustain both of these tests, and thus show that they contain fat. In a caterpillar that has been starved for several days the fat body is reduced to a few small strands of cells on the crop, but each of these cells contains as much fat as do those of the normal fat body.

Another substance stored in the caterpillar's body for future use is glycogen or animal starch, and it, too, is contained in the cells of the fat body. The fat body is, therefore, a sort of liver to the insect, since the storage of glycogen is one of the important functions of the liver in vertebrate animals. Glycogen is used up in the production of energy, and both it and the stored fat are consumed during the next stage of the insect, when the caterpillar undergoes the alterations that produce from it a moth.

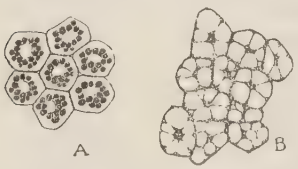


FIG. 16.—A, fat cells of a caterpillar 1½ inches long as they look when stained with osmic acid; B, fat cells of a male moth just out of the cocoon. The clear spaces are filled with an oily liquid.

During these alterations, however, business does not go on as usual. Many of the old functions are discontinued and physiological processes come into action that would be impossible in an active animal. Therefore the insect goes into a special inactive stage called the *pupa*, and some of the details of its reorganization, called *metamorphosis*, will now be described.

HOW THE CATERPILLAR BECOMES A MOTH.

When the caterpillar ceases feeding its body contains an abundance of fat, and its silk glands are more distended than at any time before. When it begins to spin its cocoon its alimentary canal contains no remains of food, the crop is contracted to a narrow cylinder and the stomach is shrunken and flabby. But the latter contains a soft, orange-brown substance, composed, not of plant tissue, but of animal cells. It is, in fact, the dissolving cellular lining of the stomach itself which has already been shed into the cavity of the stomach, and is apparently in the process of being digested by the new wall that is taking its place. This marks the beginning of the dismantling of the caterpillar preparatory to the process of reformation that is to take place—the beginning of metamorphosis.

After the caterpillar has completed its cocoon, its life as a caterpillar is almost ended. Its external appearance is already much altered by the shortening of its body and the loss of its furry covering,

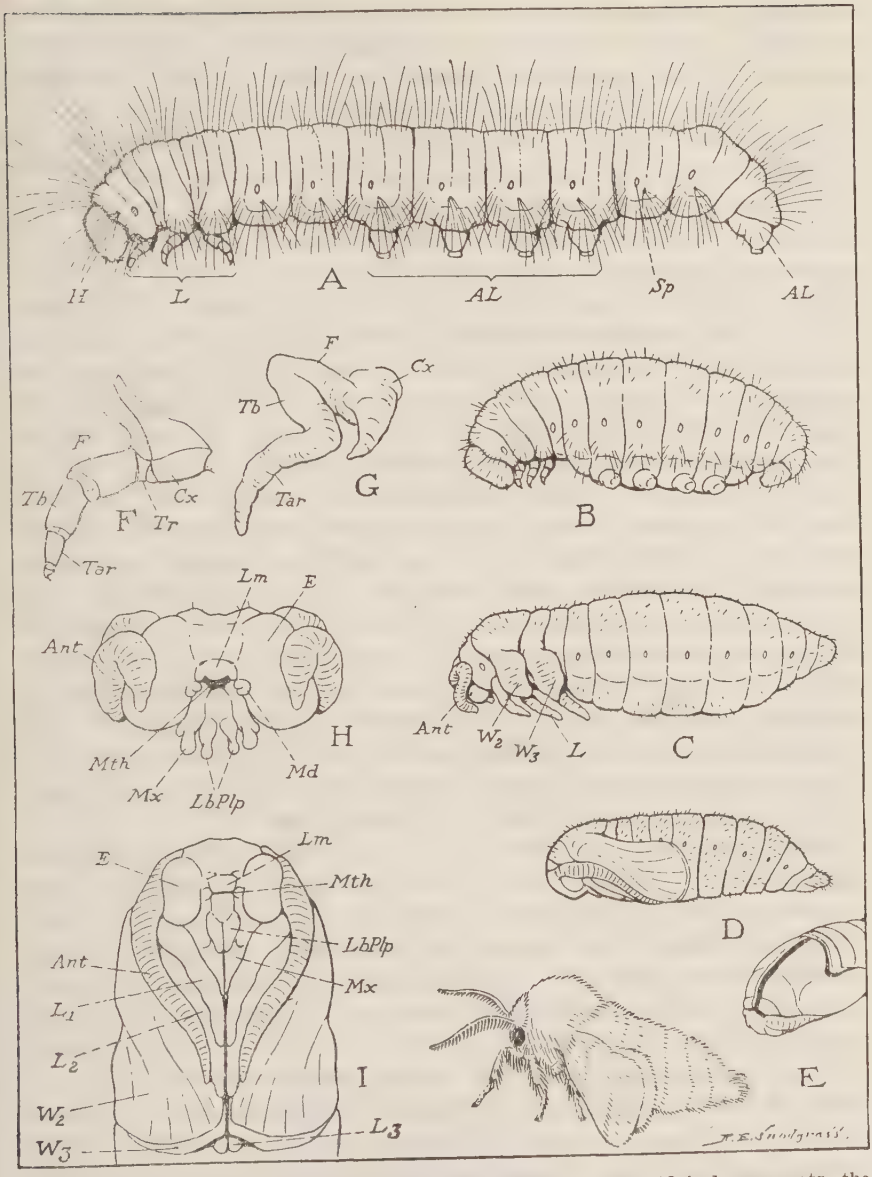


FIG. 17.—A, the mature caterpillar, showing the head (*H*) and 13 body segments, the jointed legs (*L*) on the three thoracic segments, the abdominal legs (*AL*) on the third to sixth and the tenth abdominal segments, and the breathing pores or spiracles (*Sp*) along the side of the body.

B, the contracted prepupal stage of the caterpillar in the cocoon.

C, the propupa extended after artificial removal of the prepupal caterpillar skin. The antennae (*Ant*), wings (*W*), and legs (*L*) are all free appendages.

D, the pupa, the form of the insect when the prepupal caterpillar skin is shed normally. The appendages are all glued fast to the hard shell-like body wall.

E, the empty pupal skin and the newly emerged moth.

F, a thoracic leg of the caterpillar. *Cx*, coxa; *F*, femur; *Tar*, tarsus; *Tb*, tibia; *Tr*, trochanter.

G, corresponding leg of the propupa. Only the tarsus (*Tar*) develops in the leg of the caterpillar (F).

H, the head of the propupa, under view. *Ant*, antenna; *E*, eye; *LbPlp*, labial palpi; *Lm*, labrum; *Md*, rudiment of mandible; *Mth*, mouth; *Mx*, maxilla.

I, under view of front half of the pupa. Lettering as in H; also L_1, L_2, L_3, legs; W_2, W_3, wings.

and during the next three or four days a characteristic change of form takes place. As the body continues to shorten, the first three segments become crowded together, but those of the abdominal region swell out and their legs are retracted. The creature (fig. 17, B) is now only half its former length (A) and would scarcely be recognized as the same animal that spun itself into the cocoon.

This period of the insect's life is called the *prepupal* stage of the caterpillar. Yet the creature is really no longer a caterpillar, it is simply still wearing the caterpillar's skin; and this garment can now be taken off like a coat without injury to the wearer. The latter (fig. 17, C) is then discovered to be a thing entirely different in appearance from the caterpillar (A). In many ways it suggests the future moth (E), but it is called the *propupa.* It has a pair of small wings (W_2 and W_3) on each side of the body, legs (*L*) much longer than those of the caterpillar (being folded, only the ends are visible in side view), and a pair of large antennæ (*Ant*) on the head. Its first three body segments, though all different from one another, constitute a well-defined thoracic region bearing the wings and legs, while the following 10 segments are more alike than in the caterpillar and form a distinct abdominal part of the body, swollen at the middle and tapering toward the rear end. The breathing pores along the sides of the body correspond with those of the caterpillar, except that there is an extra pore on each side between the second and third segments (but covered by the base of the front wing in the figure, C). This spiracle is present in most insects, both young and adult, and is simply overgrown by the skin in the caterpillar.

Many important alterations have taken place in the form and structure of the head and the appendages about the mouth during the change from the caterpillar, as will be seen by comparing Figure 17, H, with Figure 11. Most of the sides of the caterpillar's head, including its 12 eyes, have been converted into the two huge eyes (*E*) of the propupa, and the antennæ (*Ant*) have increased enormously in size. The upper lip (*Lm*), on the other hand, is much smaller in the propupa, the great biting jaws of the caterpillar are reduced to mere rudiments (*Md*), while the spinneret of the caterpillar (*Spn*) is gone entirely. The maxillæ (*Mx*) and labium (*Lb*) are more distinct from one another, and their parts more simplified. The labium carries two long *palpi* (fig. 17, H, *LbPlp*).

Yet, as different as are the external parts of the propupa from those of the caterpillar, they have all been formed in the corresponding organs of the latter, or at least as far as there was room for them to grow in the caterpillar parts. In the case of the antennæ only the very tips of the new organs could develop in the old, the rest had to fold back against the sides of the head beneath the skin.

In the case of the mandibles the condition is reversed—the new organs shrink to such an extent that they leave the old ones almost empty. From this we see, however, that the parts of the head of the propupa are derived from those of the caterpillar, just as are the parts in any one stage of the caterpillar, except the first, derived from those of the preceding stage, and are disclosed when the skin is shed. The change of form in the propupa is but a detail, for in some species changes take place during the molt between stages of the caterpillar.

The legs of the propupa are so much longer than those of the caterpillar that only the terminal part of each, the tarsus (fig. 17, G, *Tar*), can develop inside the corresponding caterpillar leg (F); the rest of the leg folds upward within the skin against the side of the body, just as the antennæ fold back against the sides of the head to find space for their increasing bulk. This does not mean, therefore, that the caterpillar leg represents only the tarsal part of the adult leg, though it has often been so interpreted.

The case of the wings appears to be different, for the caterpillar has no external wings at all, not even rudiments in which the propupal wings could start their growth. Consequently the wing buds are forced to grow internally. They can be found inside the skin of the caterpillar as little sacs turned outside in. When the caterpillar skin is loosened over that of the propupa the wing sacs are everted and quickly take their normal place on the outside of the body as small external lobes (fig. 17, C, W_2, W_3).

The propupa remains within the caterpillar skin for three or four days and then the latter splits open along the back of the first two body segments, over the top of the head and down the right side of the frontal triangle to the base of the right jaw. The creature within now quickly wriggles out of the skin and pushes it over the rear end of its body and into the end of the cocoon, where it remains as a hairy wad, the last evidence of the caterpillar.

The propupa (fig. 17, C) very clearly started out to be a moth (E), but the thing that appears (D) when the caterpillar skin is shed does not at all resemble a moth. The propupa, in fact, has changed to a pupa, and this (D) is a cylindrical hard-shelled creature, rounded at the head end, tapering at the other, with all of its appendages glued down fast to the body wall. Its size is much less than that of the propupa (C) and its length only about one-third that of the original caterpillar (A). The only motion it can make is a rotary, wriggling movement of the rear end of the body. A pupa of this sort is characteristic of moths and butterflies and is called a *chrysalis*. It is a specialized stage in the insect's life, which, by its compact form and shell-like skin, affords greater safety for

the period of reconstruction than would a soft-bodied thing like the propupa. The color of the chrysalis is at first bright green on the foreparts, yellowish on the abdomen, and usually more or less brown on the back. But it soon darkens till the fore parts and the wings are purplish black and the abdomen purplish brown.

The changes that have taken place in the mouth parts, antennæ, legs, and wings since the propupal period are shown at I on Figure 17. The legs and wings are folded flat against the body, the antennæ (*Ant*) are straightened out against the edges of the wings, the maxillæ (*Mx*) are longer than in the propupa (H), and the mouth (*Mth*) is closed to a narrow slit.

From now on the external form of the pupa will not change, but the processes of transformation will go on rapidly within it during the next three weeks. Then the fully formed moth will discard the pupal shell, just as the pupa rejected the skin of the caterpillar after the latter had served as a covering during its formative propupal period.

We have seen that the caterpillar's business is to eat. Its wormlike form, supposedly, is one better adapted to the securing of food than the moth form. Therefore, the young moth hatches out of the egg as a caterpillar, provided with external organs, alimentary canal, and silk glands all ready for its work, and a system of muscles that will accomplish all its necessary movements. But these parts become suddenly useless when the insect reaches the end of the caterpillar stage. Consequently they must be discarded or made over into the corresponding organs of the moth if the insect is to complete its life and produce another generation. The necessity for this change is the reason for the pupal period. The departure of the pupa from the direct road from the propupa to the adult necessitates another molt and establishes the pupa as a separate stage in the insect's growth, though it is really but the formative period of the moth and is to be regarded as a part of the adult stage.

During the re-formation it is necessary that continuity be preserved in most of the parts, else the animal would fall to pieces somewhere in the process. Reconstruction, therefore, keeps on the heels of disintegration, and in all the tissues, except some of the muscles, the newly forming parts are always present along with the remains of the old. Hence, while the external form of an organ may be changing, it always appears to be intact. It is only by a microscopic examination of tissues prepared for a study of their cells that it is possible to see what is really taking place in them. The details have been described by many investigators, who agree pretty well on the following points.

All the external parts of the insect are formed from the skin and its hard outer cuticle. The skin consists of a layer of cells and is called the hypodermis. The remodeling of the external form and organs results from a regeneration of the hypoderm. After the external parts of any stage are once formed they do not change again during that stage, but there are certain islands of cells in the hypoderm that retain their vitality till the propupal period. At the beginning of metamorphosis these cells begin to multiply rapidly and spread out in expanding patches of new skin. The old skin cells appear to be discouraged at the sight of these vigorous young cells crowding upon them; they give up at once without a fight, go to pieces, and are absorbed into the interior of the body as the new cells take their places. The islands from which the latter originated were parts of the original body segments, and each new growing set respects the boundaries of its own segment, but pays no attention to the old shape of the segment or any of its parts. Thus the newly formed insect has the same segmentation as in the preceding stage, but its shape and details may be very different.

During all this modification of the hypodermis the old cuticle covering it has remained the same. When the new hypoderm is completed, the old caterpillar cuticle is loosened and separated, while a new cuticle is formed beneath it on the surface of the new skin. This gives the wing buds a chance to evert and take their normal position outside the body. Then the old cuticle is shed and the newly formed creature is exposed in the shape of the pupa.

The original islands of regeneration cells are called *imaginal buds* (from *imago*, meaning an adult). During the pupal stage the hypoderm undergoes still further modifications, and forms still another cuticle beneath that of the pupa. Finally, the latter is cast off, and the moth appears.

But while this remodeling of the external form has been going on other changes have taken place inside the body. We have already noted that the lining of the stomach is shed at the time when the caterpillar is spinning its cocoon. But it is not all cast off—groups of small cells which, like those of the hypoderm, have not lost their vitality remain behind and generate a new lining that digests and absorbs the débris of the old. The gullet, with the crop and the intestine, being ingrowths of the hypoderm, are regenerated in the same way as the body wall. Groups of cells in their walls multiply and replace the old cells, which are absorbed into the blood. Their linings are shed with the body cuticle. The alimentary canal of the moth is very different from that of the caterpillar, but it will be described in the next section.

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The walls of the Malpighian tubules are regenerated, but the tubes do not change much in form. The silk glands are greatly reduced in size and the silk press and the spinneret are not reformed at all. The ducts of the new glands, which are to have a new function, open into the mouth.

None of these organs ever loses its continuity. Each is always present in some form during all of the pupal period. But the reorganization that affects the muscles is so thorough that many lose their integrity for a while. Some that were intended only for the use of the caterpillar are destroyed completely, others are remodeled, and new ones are built up expressly for the use of the adult.

Other internal parts, such as the nervous system, the heart, the respiratory tubes, and the reproductive organs, do not suffer any disintegration but grow to the mature form in the ordinary manner of development.

The cells of the fat body separate from one another in the pupa and float about in the body cavity as a mass of free globular cells. They give up their oil droplets either by absorption or by the dissolving of their thin walls, which scatters their contents broadcast in the blood. In some insects, however, the fat cells assume a new function during the pupal period; they absorb and appear to digest material derived from the débris of the old organs, especially the dissolving muscles, and convert this material into albuminoid products that accumulate in their protoplasm in the form of small granules. These albuminous bodies are finally reabsorbed into the blood or are liberted by the breaking of the walls of the fat cells and are used as food by the developing tissues of the adult.

From all this we see that the pupa is far from being dead; from a physiological standpoint it is very much alive and active. But its activities are not a part of the drama of the insect's life—the pupal stage is a period of intermission between the two main acts when a great commotion of scene shifting and costume changing goes on behind the curtain of the pupal shell.

THE MOTH.

For three weeks or a little longer the processes of reconstruction go on within the pupa, and then the creature that was a caterpillar breaks through its coverings and appears in the form and costume of a moth. The pupal shell splits open at the front end (fig. 17, E) to allow the moth to emerge, but the latter then only finds itself face to face with the wall of the cocoon. It has left behind its cutting instruments, the mandibles, with its discarded overalls; but it has turned chemist and needs no tools. The glands that furnished the silk for building the cocoon now, in their altered state, secrete a clear

liquid that oozes out of the mouth and acts as a solvent on the glue that holds the cocoon threads together. The strands thus moistened are soon loosened from one another sufficiently to allow the moth to poke its head through the cocoon wall and force a hole large enough to permit of its escape. The liquid from the mouth of the moth turns the silk brown, and the lips of the emergence hole are always stained the same color—evidence that it is this liquid that softens the silk. But a former writer, L. Trouvelot, actually watched a Polyphemus moth in its cocoon press the liquid from its mouth against the cocoon wall and then wait a half hour for its dissolving properties to act. Trouvelot says that the moth then emerges by separating the strands of silk without breaking a single thread. But the frayed edges of the hole left in the cocoon of the tent caterpillar by the moth show many loose ends of broken threads.

FIG. 18.—The tent caterpillar moths. A, male in natural position at rest; B, female (1½ natural size).

The most conspicuous features of the moth are its furry covering of hairlike scales and its wings. The latter are short at first (fig. 17, E), but they quickly expand to normal length and are then folded over the back (fig. 18, A). The color of the moths are various shades of reddish brown with the wings crossed by two oblique pale bands. The female (B) is somewhat larger than the male, her body being a little over three-fourths of an inch in length and the expanded wings 1¾ inches across.

The tent caterpillars performed so thoroughly their duty of eating that the moths have no need of more food. Consequently they are not encumbered with implements of feeding. The mandibles, which were so large in the caterpillar (fig. 11, *Md*), and became rudimentary in the propupa (fig. 17, H), are now gone entirely (fig. 19). The maxillæ (*Mx*), which were fairly long lobes in the propupa, have shrunken in the adult to insignificant though movable knobs at the sides of the mouth (*Mth*). The under lip or labium

(*Lb*) of the moth is reduced almost to nothing, but its palpi (*LbPlp*) are long and three-jointed. When covered with their scales these palpi form the two furry brushes that project in front of the face.

In most moths the two maxillæ are drawn out into a pair of long straps, the grooved inner faces of which are united to form a tube or proboscis through which the moth sucks up nectar from flowers and drinks water. In some species, however, such as the fall webworm moth, the proboscis is short and perhaps almost useless (see p. 411 of Smithsonian Report for 1921). In the moth of the tent caterpillar the maxillæ are so small that they do not form any proboscis at all. It is interesting to note that the maxillæ of the tent caterpillar reach their greatest length in the pupa (fig. 17, I), as if nature had intended the moth to have a proboscis, but changed her mind and had the maxillæ grow backward again in the pupal stage. When things like this take place in the development of an animal zoologists interpret it as meaning that the final form of the organ has been acquired recently, referring, of course, to the past few million years.

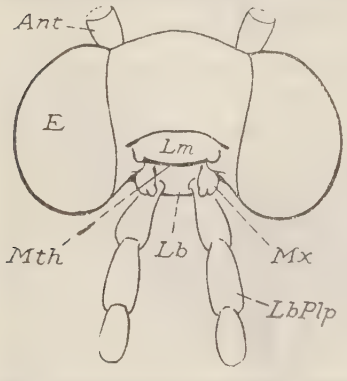

FIG. 19.—Head of the moth, facial view, with scales removed and antennæ cut off near bases. *Ant*, antenna; *E*, eye; *Lb*, labium; *LbPlp*, labial palpus; *Lm*, lagrum; *Mth*, mouth; *Mx*, maxilla.

Since the moth eats nothing and probably drinks nothing, it has little use for an alimentary canal. But important organs, though useless, are seldom obliterated. Consequently the tent caterpillar moth has a threadlike tube extending backward from its mouth which preserves the tradition of a stomach, an organ which its ancestors once possessed. The intestine is better developed, since it must still function as the outlet for the Malpighian tubules. The secretion of these tubes during the pupal period consists of minute spherical crystals. They accumulate in the rear part of the intestine as an orange-colored mass which is discharged as soon as the moth leaves the cocoon.

Most of the male moths emerge from the cocoons several days in advance of the females. At this time their bodies contain an abundance of fat tissue (fig. 16, B), the cells of which are filled with droplets of fatty oil, as shown by their staining deeply with osmic acid and Soudan III. But the internal reproductive organs of the male are not yet fully developed and probably do not become functional till about the time the females are out of their cocoons.

The body of the female, on the other hand, contains no fat tissue when she emerges, while her ovaries are full of mature eggs ready to be laid as soon as the fertilizing element is received from the male. One specimen examined contained 289 eggs, an average of 36 for each of the eight tubes of the ovaries (fig. 20, *Ov*). The material that will form the covering of the eggs when laid is a clear brown liquid contained in two great sacs (*Res*) that open into the oviduct (*OvD*). Each is the reservoir of a long tubular gland (*Gl*). The liquid must be somehow mixed with air when it is extruded over the eggs to give the covering its frothy structure. It soon sets into a jelly-like substance, then becomes firm but elastic like rubber, and eventually becomes dry and brittle.

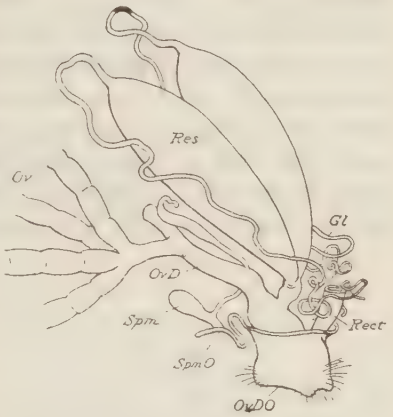

FIG. 20.—Internal organs of a female moth, showing the base of one ovary (*Ov*), the common oviduct (*OvD*) and its opening to the exterior (*OvDO*), the spermatheca (*Spm*), connected with the oviduct by a short tube, and its opening to the exterior (*SpmO*). The egg covering is formed as a brown liquid in the glands (*Gl*) and accumulates in the large sacs (*Res*) which open into the terminal part of the oviduct.

The date of the egg laying depends on the latitude of the region the moth inhabits, varying from the middle of May in the Southern States to the end of June in the North. While the eggs will not hatch till the following spring, they nevertheless begin to develop at once, and within six weeks the caterpillars may be found fully formed inside of them (fig. 21, B). Each has its head against the top of the shell and its body bent U-shaped, with the tail end turned to one side. The hairs of the body are all brushed forward and form a thin cushion about the poor creature, which for crimes uncommitted is sentenced to eight months' solitary confinement in this inhuman position. Yet, if artificially liberated, the prisoner takes no advantage of the freedom offered. Though it can move a little, it remains coiled (A) and will fold up again if forcibly straightened, thus asserting that it is more comfortable than it looks.

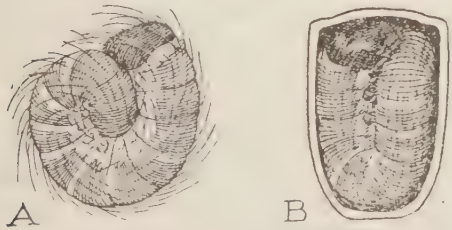

FIG. 21.—A, young tent caterpillar taken from an egg July 29; B, caterpillar in natural position in the egg.

It is surprising that these infant caterpillars can remain inactive like this all through the summer, when the warmth spurs the vitality of other species and speeds them up to their most rapid growth and development. External conditions in general appear to have much to do with regulating the lives of insects, but the tent caterpillars in their eggs give proof that the creature is not entirely the slave of environment. By some secret source of patience the prisoners will serve their time in those tiny capsules through all the heat of summer, the cold of winter, and not till the cherry buds are ready to open in the spring will they gnaw through the inclosing shells against which their faces have been pressing all this while.

THE LIFE HISTORY AND HABITS OF THE SOLITARY WASP, PHILANTHUS GIBBOSUS.

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[With 3 plates.]

Should the ordinary entomologist that tramps the field with collecting net and cyanide bottle catch sight of the small black and yellow wasp known to scientists as *Philanthus gibbosus*, he would probably pass it by as a specimen scarcely worth a sweep of his net. True, it is an insect not rare, nor even handsome, nor deserving of much comment when pinned in a cabinet. But, like all the solitary wasps, it lives a life of extraordinary interest, fascinating for the biologist and the layman alike.

The habits of this Philanthus have previously been studied to some extent by the Peckhams[1] in Wisconsin (1897) and by the Raus[2] in Missouri (1918). These veteran observers have made known the general behavior and the most conspicuous features in the life history of the wasp. The observations described in this paper disagree in no essential point from those of the older writers. The present writer's aim has been to supplement our knowledge and to remove lacunae, so as to present the life history of Philanthus as a nearly complete biography rather than as a cursory sketch.

DESCRIPTION, SYNONOMY, DISTRIBUTION.

Philanthus gibbosus is a small but robust wasp, 10 to 12 millimeters in length (pl. 1, fig. 1). She has a broad head that seems almost too large for the dwarfed body. Her coat of chitin is shiny black with spots of yellow on the head and yellow bands on the thorax and abdominal segments. The very large and deep punctures on the abdomen of this insect make it an easy species to recognize. These conspicuous punctures suggested Say's name of *Philanthus punctatus*. Under this title the wasp has commonly been referred to, but Mr. S. A. Rohwer has recently examined into the synonomy of

[1] Peckham, G. W. and E. G. Instincts and Habits of the Solitary Wasps. Wisconsin Geol. and Nat. Hist. Survey. Bull. 2, Sc. Ser. 1, pp. 117–124.

[2] Rau, P. and N. Wasp Studies Afield. Princeton University Press, pp. 109–116.

this species and believed it necessary to change the name to *P. gibbosus* Fabricius, a synonym that was intimated by Dalla Torre but was not generally followed in America.

The male of *gibbosus* resembles the female very closely, but differs mainly in having less yellow on the head (fig. 1). This is the opposite of the usual sexual diversity in Hymenoptera. Most male wasps and bees have more light-colored markings on the face than the female.

Philanthus gibbosus is a common and widely distributed Sphecid of North America. Specimens in the United States National Museum collections show a habitat that extends from Washington, Colorado, Arizona, and Texas in the West to Georgia, Virginia, New York, and Massachusetts in the East. There are specimens in

FIG. 1.—Philanthus gibbosus. Heads of male and female.

the collections of the National Museum from 21 States, as well as from Canada and Mexico.

THE ANNUAL CYCLE.

In Maryland *Philanthus gibbosus* goes through two generations a year. The early pioneers begin prospecting for a nesting site during the second week of June; but some laggards do not start to dig until two weeks later. By the end of June the establishment is in full swing. For about three weeks each wasp applies herself to the task of provisioning and egg laying, and then, her season over, she dies.

During the middle of July the progeny of this first brood begin to make their appearance, and the gradual emergence continues until almost the end of August. The major number of this second generation have provided for their young and died before the beginning of September. A few stragglers, however, keep on with their task until more than a fortnight later. The larvae pass the winter in their cocoons, change to pupae in April, and emerge during May and June, and thus one annual cycle is complete.

NESTING SITES.

An uncemented brick walk which surrounds the main building of Woodstock College, Woodstock, Md., was a favorite nesting site for *Philanthus gibbosus*. The wasps tunneled down between the bricks and built their cells in the sand beneath. The greater number had selected a portion of the path which was sheltered from the rain by a wide, projecting balcony. Though it was on the northern side of the building and received only the late afternoon sun, this section of about 35 yards was strewn with the excavated sand of nearly a hundred burrows. It was a curious instance of phototaxis that the mouth of every burrow opened toward the light; not a single doorway was found which faced the side of the building. This colony was kept under observation for two years, and it was here that most of the information for the present paper was gathered.

Under the broad eaves of another building a second group of nearly 30 Philanthi had settled close together in tenement fashion in a spot of hard ground which bore a scant growth of chickweed and foxtail grass.

A smaller colony, numbering about a score of nests, had also become established in the hard-packed clay of a tennis court; another group chose a bare slope in an open grove of trees.

Isolated nests were likewise found, one in the midst of a lawn, and several others along the bank of a roadway.

THE BURROW.

During the season of the wasp's activity, from the middle of June to the middle of September, small scattered heaps of sand upon the loose bricks of the path betray the entrance to the storerooms of Philanthus. One might at first credit the heaps to the home building of the ubiquitous ant, but these piles of sand are flat and spreading and do not form such a neat architectural dome as the ants are wont to erect. Should you chance to find Philanthus at work on her burrow you would see her backing out of the earth with a load of moist sand, which she pushes clear of the tunnel and then spreads over the heap with queer little jerks of her front legs. During the proceedings she stands on her four hind feet, the last two spread widely apart, and with the front ones scoops up the sand and shoots it backward beneath the arch of her body. It falls far in the rear in rapid, dusty jets, and with each strenuous dig and toss the wasp teeters sharply up and down like a toy rocking-horse. The front tarsi are often the main fossorial tools of a wasp, and those of Philanthus (fig. 2), with their spadelike calcaria, are well equipped for their work.

The large amount of dirt carried up from below and spread before the entrance gives indication that the burrow is a long one and leads far into the earth; and, indeed, Philanthus, with her tarsi and mandibles, often digs a shaft that is 2 feet or more in length. From one edge of the pile of sand a narrow, tortuous tunnel descends obliquely into the earth for about 6 inches, then swings around to run in a horizontal direction for 15 more, and finally ends in a neatly rounded oval cell (fig. 3). Other cells are disclosed, but these have no direct communication with the main corridor. From their contents we gain a clue to the plan of the architect. The chamber closest to the entrance is strewn with the skeletons of Halictine bees, and on this heap rests the consumer's cocoon. We break into the next cell and find a full-grown larva munching its last mouthfuls of bee flesh. The succeeding cells show us larvae growing fat on their provisions, each larva a little younger and smaller than the preceding. The penultimate pocket contains the wasp's egg, while the terminal cell is as yet unprovisioned. From this arrangement it is clear that the oldest cell is the one nearest the opening of the burrow. Each cell was in turn a terminal pocket which was fashioned only when needed. After completion its connection with the main gangway was blocked and the gallery was pushed onward to form another pocket. In due time this was likewise provisioned, tenanted, and sealed, and so the work proceeded until the wasp had enough separate nurseries to house her entire offspring.

FIG. 2.—Philanthus gibbosus. Fore tibia and tarsus of female. (× 36.)

The illustration (fig. 3) is meant to represent a typical burrow. Scores of nests were excavated and all conformed more or less to this general type in inverse proportion to the stony nature of the ground. One wasp had met with so many obstacles that the terminus of her burrow was only 2 inches from the entrance—she had tunneled in a circle.

THE EGG AND LARVA.

The egg of the Philanthus (pl. 1, fig. 2) is a smooth, banana-shaped capsule, lustrous white, with a very thin, transparent chorion. Its length is between 3 and 4 millimeters; its greatest width is about

eight-tenths of a millimeter. Queerly enough, it is usually secured to the sternum of one of the smaller *Halictinae*, so that it often stretches along the bee's entire length from chin to tail. Knowing that the bees are butchered and not paralyzed, one might suspect that the egg would be laid on the first carcass brought in. We might reason that the sooner the egg is laid the sooner will it hatch and the fresher will be the food supply. But facts confound our logic. It is always on the last bee stored away, on the bee resting on the top of the heap, that we find the wasp's egg. Nor are the provisions uncommonly well preserved. Long before the Philanthus larva has ceased feeding there is a decidedly unpleasant effluvium coming from the corpses which form its food.

FIG. 3.—The underground nest of Philanthus gibbosus, one-third natural size.

Within three days the egg hatches, not suddenly, but gradually and almost imperceptibly. Inside the forward and blunter end of the egg the embryonic larval head has been forming and the segmented body begins to fill the membranous shell. Then the larva, without moving, pierces the skin of the egg directly below its mandibles and begins to draw nourishment from between the sternal sclerites of the bee. The swelling larval form at length bursts the tight envelope of the shell. It splits and shrinks away, leaving the larva a suckling at the breast of a dead bee (pl. 1, fig. 3).

The next seven days are a glorious banquet for the eupeptic grub. The tiny creature munches methodically, and methodically grows fat. Twenty-four hours after hatching it takes a short rest to shed its first moult. During the course of its growth two other sloughs are cast. The second and third ecdysis I have not witnessed, but I conjecture

their existence from a study of the changes in the shape of the larval mandibles.

After a week of feasting on honey-flavored meat the larva has reached its full growth. Nothing savory remains to be eaten. The cell is cluttered with the unpalatable legs, wings, and horny armor of the bees.

FIG. 4. — Philanthus gibbosus. Head of full-grown larva. (× 36.)

Now we can examine the larva (pl. 2, fig. 5) more carefully and correlate some of its habits with its structure. It has a body that is slender and fusiform, all covered with a stubble of short, brown bristles. The head is very small and for that reason well suited to pry into the narrow foramina of body walls to reach the food that is stored away in stout, chitinous boxes. The anal segment of the larva ends in a subcylindrical projection which is often telescoped in and out of the abdominal somites. This tail makes a handy lever for propulsion when the grub has need to shift its position. The tail is withdrawn, pressed against a fulcrum, and extended. The extension gives a propelling force to the whole body, and the grub with his caudal prolongation poles his way around the narrow confines of the cell.

FIG. 5.—Philanthus gibbosus. Larval mandibles, showing progressive changes from newly-hatched larva to prepupal form. Drawn to scale. (× 150.)

The microscope reveals nothing exceptional about the larva's head (fig. 4). The lower margin of the clypeus is notched, and its sides shield two teeth of the tridentate mandibles—these may be characters of interest to the taxonomist.

A study was made of the mandibles from the newly hatched larva to the adult, and it showed an interesting mutation in these organs.

In figure 5 four mandibles are shown, corresponding to the four larval instars. Each stage exhibits a progressive lengthening and narrowing of the mandibular shaft, and a blunting and equalizing of the teeth. This development continues during the pupal stages (fig. 6) where two of the teeth become obsolete, and finally results in the long, acuminate mandibles of the imago (fig. 1).

THE COCOON, PUPAL PERIOD, EMERGENCE.

Thus far in its career the larva has shown no talents save those of a butcher and a trencherman. Now it will weave a silken teepee to shelter it during the critical period of the transfiguration. The cocoon (pl. 2, fig. 10) when completed is a bulbous case composed of a single ply of homogeneous, straw-colored silk. These silken walls are sometimes obscured by a white cottony flock which rubs off readily and leaves the cocoon almost as translucent as an amber bead. It has the shape of a very long pear, with its tapering neck, colored brown by the stercoral plug securely fastened to the rear wall of the cell. The blunt end is free and invariably points toward the mouth of the burrow, the corridor for exit.

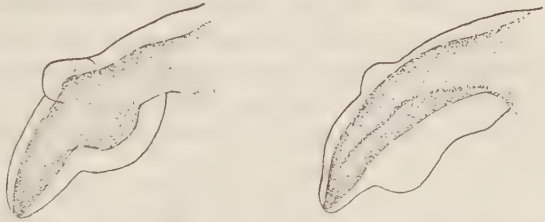


FIG. 6.—The pupal mandibles of Philanthus gibbosus. The chitinized mandibles of the adult are shown in formation within the swollen, fleshy mandibles of the pupa. Mandible of white-eyed pupa at left, of black-eyed pupa at right. (× 36.)

It takes the insect weaver 48 hours to complete its cocoon. As a sort of preliminary scaffolding the larva spins a loose, cobwebby hammock in the cell. This much, though mere preparation, requires 15 hours of labor. Then a light silk bag is spun on this support. Its tip is open and attached to the wall. Toward the end of the task the open tip is sewed up. Last of all, two days after the abode is completed, the occupant fits its faeces into the narrow neck, and with that act all larval activity ceases.

Eight months pass, and the larva sleeps on in its silken flask. The chemicals are mixed, the retort filled, but the flame has not yet been applied. At last the long lethargy reaches an end, and the shapeless grub is metamorphosed into a nymph. But should the grub belong to the first generation it will take only a week's siesta in preparation for the nymphosis. Then the larval wrapper is thrown off and the delicately-molded pupa (pl. 2, figs. 6, 7, 8) makes its appearance. The transitory pupae that link larva to wasp are feeble, grotesque organisms, mere ghosts of the perfect insect. They look

like uncompleted statuettes, like alabaster carvings waiting for the breath of life. The pale pupae gradually don the livery of Philanthus. Their white eyes change to brown after two days, then to black after four more days, and before another week has elapsed the coloration is complete.

The length of the pupal period varies presumably with the weather. Three male Philanthi pupated on April 15. One emerged as imago after 27 days, the other two after 28 days. In July, however, one female required but 19 days and another only 15 days to complete its transformations.

When the time has come for the emergence the wasp with her powerful mandibles attacks the blunt end of the cocoon (pl. 1, fig. 4). A few lusty strokes and the imago is free. Patient digging in the right direction will demolish the barricade between the cell and the main gallery, and before long another Philanthus is ready to ply its trade of bee butchering.

The adults of many colonial wasps emerge in a body, as if at a given signal, and then hold riotous mating flights in the sunshine. But the Philanthus clan muster their numbers only very gradually. While the oldest cell is already vacated by the fully-formed imago, the last cells of the same burrow may contain but a prepupal larva.

DOMESTIC AFFAIRS.

For some time after emerging the youthful wasps share together the ancestral cave, and on a bright morning one can see framed in the doorway the stolid yellow face of a female, or the black-barred visage of a male. When and where the couples formed could not be determined. Frequent visits to the near-by flowers showed Philanthi of both sexes feeding quietly together in large numbers, but in perfect disregard of each other. Daily observation at the nesting site failed to disclose a single endeavor at copulation. It seems probable therefore that the nuptial ceremonies are conducted within the nest, and possibly within the old nest previous to the dispersal of the clan. If this be so we wonder what provisions are made to avoid the dangers of inbreeding. The underground cave is also used as the wasp's dormitory and crypt. The matron of the nest always spends the night at home. Toward 5 o'clock or later in the afternoon she bars the door of her dwelling with a plug of sand pushed up from within. Her rest will be secure unless Harpalus or some other night-prowling beetle blunders in. The callow males at first patronize the home dormitory, but later on they sometimes dig individual lodgings of their own, whither, as the Peckhams relate, they retreat night after night for slumber. The female Philanthi have a strenuous but brief existence. For them there is no lingering senescence. It is not unusual when excavating a burrow to find in the terminal

cell a moldering harvest of bees and the harvester's corpse. Death takes Philanthus in the midst of labors.

THE PROBLEM OF THE PREY.

Previous observers had reported that Philanthus provisioned its nest with bees of the genus *Halictus* (sensu latiore). Ashmead and the Peckhams have recorded the use by Philanthus of *Helictus disparalis* Cres.; while the Raus noted that the wasp took *H. versatus* Robt., *H. pruinosus* Robt., and *H. sparsus* Robt.

More extensive investigations were undertaken by the writer to determine if possible whether Philanthus restricts her captures entirely to Halictine bees. At various intervals during the four months of the wasp's activity her burrows were ransacked and rifled of their contents. The loot of two seasons amounted to 331 bees. When these were sorted and determined they comprised 22 species, 21 of which belonged to the family *Halictidae*.

The complete catalogue is as follows:

Catalogue of the prey found in the nests of Philanthus gibbosus.

Type.	Species.	Length.	June.	July.	August.	September.	Total.
		Mm.					
A	Augochlora viridissima Vier	7–8	2	12	4	5	23
W	Augochlora fervida Sm	9			1		1
B	Oxystoglossa pura (Say)	5–8	5	18	15	4	42
H	Halictus ligatus Say	6–8		12	49		61
I	Halictus lerouxi Lep	9	1				1
D	Chloralictus sparsus Robt	3–5	15	41	16	5	77
C	Chloralictus illinoensis Robt	4–5		1	2	18	21
C	Chloralictus sp. near zephyrus Sm	4–5	1	17			18
X	Chloralictus pilosus (Sm.)	5–6		5	1		6
DD	Chloralictus cressoni ? (Robt.)	5–6		4	1		5
E	Chloralictus obscurus (Robt.)	6–7	1	1		2	4
N	Chloralictus viridatus Lov	6		2			2
CC	Chloralictus versatus Robt	4–7		2			2
S	Chloralictus caeruleus Robt	5		1			1
F	Seladonia provancheri (D. T.)	6–7		22	8		30
G	Curtisapis coriacea (Robt.)	8			1	8	9
BB	Curtisapis fuscipennis (Sm.)	9	1				1
Y	Evylaeus arcuatus Robt	7–8	2	10			12
J	Evylaeus pectoralis (Sm.)	5–6		5	1		6
AA	Evylaeus sp. ?	5	1				1
T	Dialonia antennariae (Robt.)	4		2			2
U	Calliopsis andreniformis Sm	5–6		2	4		6
							331

Specimens of all these species have been placed in the collections of the United States National Museum. Each one is designated by its respective type letter and bears the label "Prey of Philanthus gibbosus."

In compiling the catalogue I have followed the classification and nomenclature of Charles Robertson. The genera are therefore used in the Robertsonian sense. According to the commoner classification, the first 20 bees on the list would be placed in the genus *Halictus*. These 20, with *Dialonia antennariae*, which is a *Sphecodes*, belong to the family *Halictidae*. *Calliopsis andreniformis*, however, belongs to the family *Panurgidae*. This latter species, of which one female and five males were found in the cells of the wasp, bears a superficial resemblance to *Halictus ligatus*.

Shall we say that the capture of these six Panurgid bees was accidental? Shall we set it down as a mistake on the part of a Philanthus who was deceived by a superficial similarity between *Calliopsis* and *Halictus*? That we should have to do if we were certain that the wasp actually selects *Halictidae*. To make such an exclusive choice the wasp must possess a remarkable instinct. Size affords no reliable guide when the bees to be chosen vary from 3 millimeters to three times that in length. Color is still more confusing. The prey of Philanthus includes bees clad in brown or dull russet; others are girdled with yellow, banded with white, adorned with hoary wool; others are bright metallic green, red, blue, ebony black, or golden green; and underneath this variety of garb and livery the wasp must recognize the invariable Halictus. Endowed with such a talent, the Philanthus would be a rival to expert melittologists; she would have more skill than our professional classifiers—a conclusion that Henri Fabre would most heartily indorse.

But the problem permits of another solution. It can be solved by saying that Philanthus takes any bees of proper size that visit the flowers during her hunting season. Halictid bees are captured in such abundance not because the huntress is a specialist on *Halictidae* but because they form the almost exclusive population of the summer field flowers. This solution is plausible enough, but requires for proof more study and experiment than I have been able to give the question.

A third suggestion is possible. In our neighborhood I have seen *Philanthus gibbosus* hunting or feeding on the flowers of Wild Carrot (*Daucus carota*), Yarrow (*Achillea millefolium*), Daisy Fleabane (*Erigeron ramosus*), Lady's Thumb (*Polygonum persicaria*), and the cultivated Gaillardia (*Gaillardia grandiflora*), and Chinese Woolflower (*Celosia plumosa*) in the garden. These are all flowers whose surgary corollas are patronized largely by *Halictidae*. It might accordingly be suggested that the preponderance of Halictid prey is an accident resulting from the partiality of Philanthus for flowers which *Halictidae* prefer. But this answer of itself scarcely solves our difficulty. It merely leads to another question: Does Phil-

anthus capture *Halictidae* because she just happens to visit the Halictid flowers, or does she visit the Halictid flowers for the purpose of capturing *Halictidae?*

But we must remember that in raising questions of this nature we are presupposing that our taxonomic groups are perfectly natural ones. Has not this discussion arisen because *to our notions Calliopsis* does not belong with the *Halictidae?* I have a suspicion that the *Panurgidae* could readily be brought together with the *Halictidae* under the same family. If these two families were merged on a natural basis it would prove a magnificent compliment to the entomological instinct of Philanthus. "Ask the beasts and they shall teach thee," and it is not improbable that Philanthus is offering taxonomy a hint which taxonomy might profitably consider.

THE MENU OF BEES.

I hasten to abandon these conjectures for the secure pathway of fact. To each cell the provident wasp furnishes a supply of from 8 to 16 bees. The contents of three cells belonging to a burrow opened on July 7 will show how varied is the menu which Philanthus supplies her offspring.

Chloralictus sparsus	10♀	Chloralictus sparsus	3♀
Oxystoglossa pura	2♀	Seladonia provancheri	2♂
Evylaeus arcuatus	2♂	Evylaeus arcuatus	1♀
Evylaeus arcuatus	1♀	Halictus ligatus	1♀
Chloralictus viridatus	1♂	Chloralictus caeruleus	1♀

Chloralictus sparsus	8♀
Chloralictus versatus	1♀
Chloralictus versatus	1♂
Dialonia antennariae	1♂

If each wasp provisions 10 cells, what a record of butcheries she must have to her credit! The colony of Philanthi under observation was responsible for the destruction of several thousand *Halictidae* every season. Because of its wholesale massacre of beneficial bees, *Philanthus gibbosus* must be classed as an injurious insect.

THE BUTCHERING OF THE BEES.

The question of the prey may be looked at from another viewpoint. The bees brought home from the hunt are often thickly powdered with pollen—a fact that would lead one to suspect that the unfortunate bee was caught and killed so quickly and skillfully that there was not even a strugggle. Such was actually the case in the encounter which I witnessed on an umbel of Queen Ann's Lace. A Philanthus was sipping nectar on the dome of florets and moving

quietly from cup to cup. Suddenly she made a dart for the edge of the umbel—the next instant I saw her standing upright, holding a small bee face to face and stinging it upwards under its chin. One dagger stroke and the fight was over. Philanthus grasped her victim and flew off. The whole operation did not take more than 10 seconds.

This capture which I observed was prettily and neatly done, but oftentimes the wasp is only a blundering bungler. She will hover over a flower and pounce on spider, fly, bug, or wasp that looks small enough to be an easy victim. I have even seen her deceived by the dark central florets in the white disk of Queen Ann's Lace, at which she would dart with amusing ferocity. Actual proximity shows her the mistake, and she makes off to fall into other errors of insect myopia.

THE RETURN FROM THE CHASE.

It is interesting to post oneself at the galleries of Philanthus to watch the wasps return from the chase laden with their prey (pl. 3, fig. 11). Their flight is easy and unimpeded by the burden. If one looks closely one can see that the wasp carries the limp carcass of the bee tightly clasped to her breast with her middle pair of legs. Sometimes she also grabs the bee's antennae in her mandibles, so that in case of emergency, when all six legs would be needed, the bee need not be dropped. It happens sometimes in walking that the legs release their grasp, but the bee is dragged along by the grip which the wasp has of its antennae. In picking up the bee the wasp first gets a mandibular hold of its antennae and then swings it into position under her body. The wasp that is bringing home prey descends to her nest in a rapid, swinging, zigzag flight. Usually little difficulty is experienced in finding the right burrow. The wasp alights, quickly removes the barrier of sand at the entrance, and disappears down the hole. Generally Philanthus effects a neat and rapid entrance without releasing her burden, though at the moment when the wasp tumbles down the shaft she shifts the bee a bit to the rear so that its abdomen projects slightly beyond her body.

AN AUTOPSY OVER THE VICTIMS.

If we play the coroner and hold an autopsy over the victims, it becomes evident that one and all were fatally stabbed in the brain. The bees that are taken from the wasp in transport all exhibit strong reflex movements. The tarsi tremble, the legs are flexed, the abdomen twitches spasmodically, but the antennae and mouth parts are almost totally inactive. These latter organs are directly in-

nervated by the brain, or, more properly, by the suboesophageal ganglion, and would be the first to be affected by its lesion. The postmortem activity of the other parts of the body is readily understood when we remember that the abdomen, thorax, and thoracic appendages are provided with special ganglia which may, even for a short while after the brain is destroyed, still perform their function of stimulation, though no longer of coordination. The legs and abdomen quiver actively at first, but the movements gradually grow feebler and cease altogether after two or three hours. Then complete immobility ensues. Electric and chemical stimulation bring no response. Soon comes desiccation and decay.

NATURAL ENEMIES.

No wasp's history could be called complete without mentioning the concomitant ravages of those professional parasites, the Tachinids. The persecutor of Philanthus is a dapper little fly, clad in pearl gray with markings of rich seal-brown. Her eyes, red as gobs of clotted blood, border a silvery face: hence she is placed on record as *Metopia leucocephala* Rossi (det. Dr. J. M. Aldrich). Daily during July and early August several of these white-faced flies can be seen poking around from burrow to burrow in the populous colony of Philanthus. An open tunnel suits the parasite's designs. With gingerly haste she steps just inside the threshold, pauses a moment, then scurries out and makes off. Never was she seen to enter a burrow more than two or three inches. Since the hoary-headed Metopia is viviparous, I presume that she releases several live maggots at the entrance to make their way unaided into the cells of the wasp.

Another intruder in the burrows of Philanthus is *Senotainia trilineata* Van der Wulp (det. Dr. J. M. Aldrich), of smaller form than Metopia but no less destructive. On July 22 two brood chambers of Philanthus were discovered which were parasitized by two maggots apiece. The marauders were feasting on the store of bees, and there was no trace of the wasp's larva or egg. These maggots formed puparia within two days, and the adult Senotainiae emerged, one on August 9 and three on August 10.

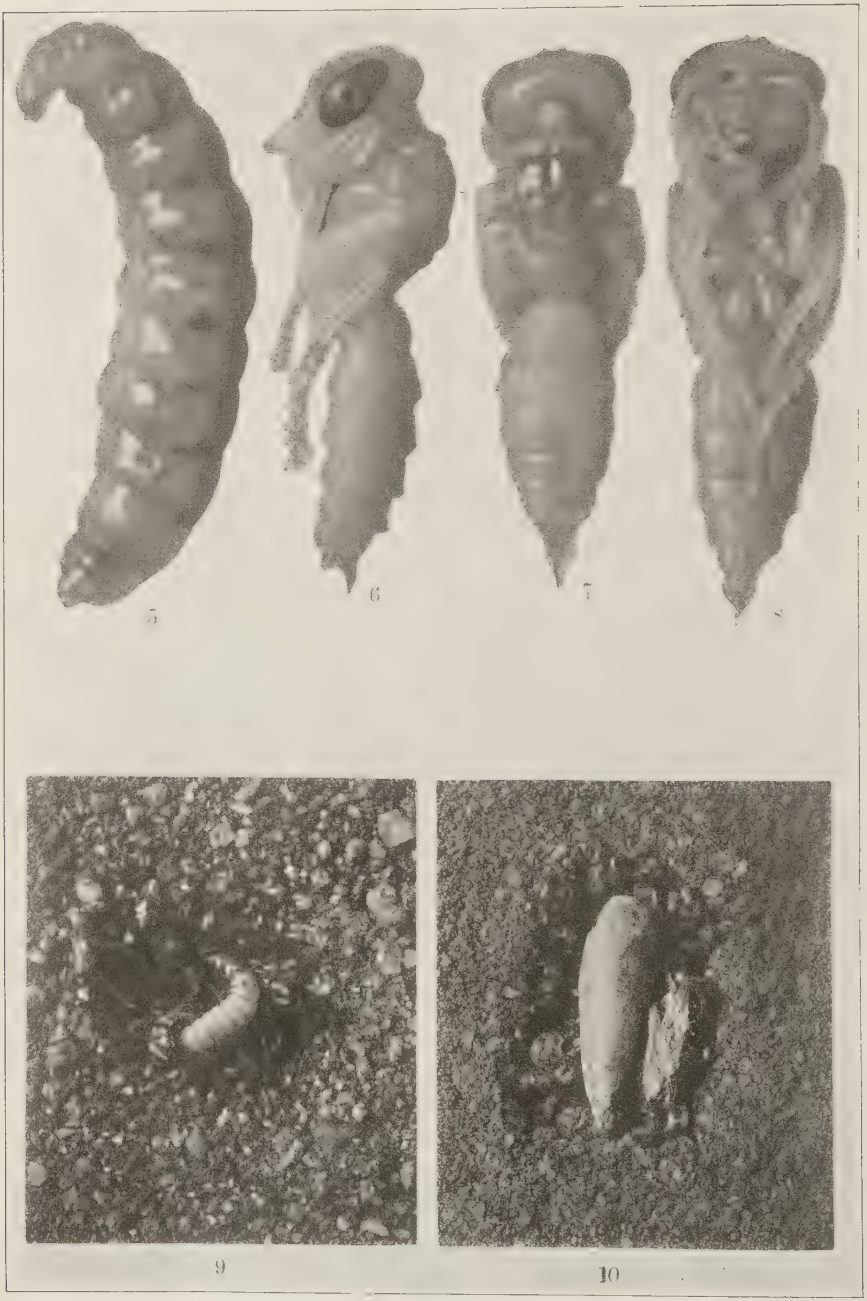
The adult wasp also falls a victim to predatory enemies. A female Philanthus was found lying on the florets of goldenrod with a yellow spider (*Misumena vatia*) sucking at her abdomen.

At Fordham University, during August, 1923, after the foregoing notes were completed, I observed another enemy of Philanthus. The incident occurred in a colony of *P. gibbosus* that had settled in a characteristic nesting site under the brick pavement of an open auto shed adjoining the Fordham faculty building. A large brown Asilid had discovered that this Philanthus colony was a profitable spot for

piracy. Frequently the robber-fly would come and crouch motionless near the nests, alert for booty. Whenever an unsuspecting wasp drew near, swiftly the Asilid would rise and strike at it hawk-like with legs extended; but most often the intended victim escaped. The home-coming Philanthi laden with their bees fell more easily into the pirate's clutches. One case in particular is worth recording. As the wasp burdened with its bee came into sight the robber-fly pounced upon it and caught both the wasp and her prey between its long spiny legs. Then with its two captives dangling from its talons the Asilid flew off. I followed to see the finish. The tableaux was remarkable. The fly hung nonchalantly by one leg from a near-by branch and with its sharp beak drained the juices of its double catch. The incident was not without dramatic irony—the assassin being despoiled by another assassin. To complete the tragedy I captured the second assassin. When its Bertillon prints were taken the robber-fly was found to be *Deromyia discolor* Loew (det. Dr. Aldrich).

I wish to acknowledge my indebtedness to my friend, Rev. John A. Brosnan, S. J., of Woodstock College, for his valuable services in taking the photographs for this paper. To Mr. Sievert A. Rohwer, of the United States National Museum, I am also obliged for determining nearly all the species of Hymenoptera involved in this discussion and verifying my determinations of the rest. For this and other assistance which Mr. Rohwer rendered me during the preparation of this paper I am happy to express here my sincere gratitude and appreciation.

1. PHILANTHUS GIBBOSUS, FEMALE. (X5.)
2. THE EGG OF PHILANTHUS SECURED TO THE VENTRAL SURFACE OF A SMALL HALICTINE BEE. (X6.)
3. NEWLY HATCHED LARVA OF PHILANTHUS BEGINNING TO FEED. (X6.)
4. IMAGO OF PHILANTHUS GIBBOSUS EMERGING FROM COCOON. (X5.



5. FULL GROWN LARVA OF PHILANTHUS. (X 6.)
6. PUPA OF PHILANTHUS, LATERAL ASPECT. (X 6.)
7. PUPA OF PHILANTHUS, DORSAL ASPECT. (X 6.)
8. PUPA OF PHILANTHUS, VENTRAL ASPECT. (X 6.)
9. A PHILANTHUS CELL, SHOWING THE LARVA AND ITS PROVISIONS. (NATURAL SIZE).
10. PHILANTHUS CELL, SHOWING THE COCOON AND FOOD DÉBRIS. (X 2.)

11. PHILANTHUS IN FLIGHT, TRANSPORTING HER PREY. (X 7.)
12. PHILANTHUS GIBBOSUS AND SOME SPECIMENS OF HER PREY. THE WASP IS IN THE CENTER FOR COMPARISON. THE BEES, BEGINNING WITH THE LARGEST AT THE TOP AND GOING CLOCKWISE ARE—ANGOCHLORA VIRIDISSIME ♀, EVYLAEUS PECTORALIS ♀, HALICTUS LIGATUS ♀, CHLORALICTUS ILLINOENSIS ♀, CURTISAPIS CORIACEA ♂, SELADONIA PROVANCHERI ♂, CHLORALICTUS OBSCURUS ♂, CHLORALICTUS SPARSUS ♂. (X 2.)

THE USE OF IDOLS IN HOPI WORSHIP.

By J. Walter Fewkes,
Chief, Bureau of American Ethnology.[1]

[With 6 plates.]

INTRODUCTION.

Very little has been published on the forms, distribution, uses, and ethnological significance of idols among North American Indians. This poverty of our knowledge evidently either is due to a neglect to study these objects by ethnologists or may reflect the relatively small number of Indian tribes in which elaborate idol worship formerly flourished or still survives.

The early accounts of the southern Indians of the Mississippi Valley contain descriptions of the employment of idols in religious rites, and many archeological collections from that region contain stone or clay images that may have served for idols. As we approach the Mexican border, in the Southwest, the relative number of these images increases. Early writings on Mexico, Central America, and the West Indies contain frequent references to idolatry, and many idols existing in Mexican collections have been found in prehistoric mounds. There are only a few localities in the United States where both ethnologists and archeologists find these evidences of idolatry plentiful. One of these is the pueblo region, or, as generally called, the Southwest. The living Indians of this region are survivors of a peculiar culture in which stone idols were abundant and the archeologist has recorded a large number of these images as found in this area. It is instructive to remember that the ancient pueblo cult was continued into modern times and in some instances old idols are heirlooms and are regarded reverently in modern times. It is very generally stated by Hopi priests that idols, like other cult objects, came from the underworld and were inherited by their ancestors from the earliest men who emerged from that place.

[1] This article is the fourth of a series on the Hopi religion published in successive annual reports of the Smithsonian Institution. The following have already appeared: (1) Sun Worship of the Hopi Indians (1918); (2) Fire Worship of the Hopi Indians (1920); (3) Ancestor Worship of the Hopi Indians (1921).

The survival of ancient objects into modern times among the pueblos is a fortunate condition for one who desires to interpret them, as it enables him, through comparative studies, to learn their meaning and interpret the rites performed with idols of similar form in ancient times. These indications point to the conclusion that there is no break in the cultural sequence of cliff dwellers and pueblos. There has been a shifting of population by migration, union, or disintegration of clans or social units and extinction of ceremonies by death of clans, but no essential difference can be detected between ancient and modern pueblos. There is a continuous growth in culture with no great break in character from the ancient into the early historic life.

For several years the use of idols in Hopi worship has been a subject of investigation by ethnologists, and we have better material from this tribe than from any other pueblos. It is also worthy of note that several idols are peculiar to certain clans (Snake and others) and that those Walpi idols that were reputed to have been brought from the north are identical with idols of the cliff dwellers. We may interpret this similarity as one more evidence, supporting many others, that the ancestors of certain clans of the Hopi were cliff dwellers.

The places where idols are most commonly found are in shrines or on altars erected at the time of great ceremonials. A shrine (pl. 1, figs. 1 and 3) is a house (*pahoki*) where a prayer stick is deposited to a god and is spoken of as the prayer-stick house of a supernatural being, and often there stands in it an idol representing that being. Cliff dwellers' shrines are difficult to recognize, but those of prehistoric pueblos have repeatedly been discovered. Up to last summer (1922) shrines had not been recognized on the Mesa Verde, but elsewhere, as at Zuñi and Walpi, they are well known, the latter having been enumerated and described by the author in an elaborate article. As is well known, shrines to the world quarters are found near most pueblos, ancient or modern, and have a general similarity in form, being a small cairn or stone inclosure, sometimes with a flat stone roof but generally open to the east. The Sun shrine at Zuñi is a good example of a simple shrine still used. The Alosaka shrine at Awatobi[2] is a shallow depression in a rock with a wall before it. Sometimes the door of a shrine is closed and a stone slab luted in place with adobe and opened only when a ceremony is about to be performed. The idol of Talatumsi belongs to the group of closed

[2] Notwithstanding the fact that the Hopi pueblo Awatobi became a ruin in 1700, this shrine was used up to about 1889, when the two idols of Alosaka which had stood in it many years were taken away and carried to another shrine at the Middle Mesa. The incident connected with their removal is referred to in the author's account of the excavations at Awatobi in 1895. (See 17th Ann. Rept. Bur. Amer. Ethn.)

shrines. In the New Fire ceremony it is carried up the mesa and placed on top of the different kivas to receive the prayers of the faithful. The late excavations on the Mesa Verde National Park have revealed several shrines and idols. Three shrines have been discovered outside a ruin in the Mummy Lake cluster of mounds. One of these, at a ruin called Pipe Shrine House,[3] is attached to the outer northeast corner of the ruin, another is situated a few feet south of the south wall, while a third lies in the cedar forest some distance south of the ruin. The shrine on the northeast corner contained a slab of stone on which a circle was cut like that in the Zuñi Sun shrine. In the south shrine there stood a mountain lion idol surrounded by many waterworn stones. In the Sun shrine there were many waterworn stones, a meteorite, and numerous other objects.

When one enters a Hopi house where there are children one's attention may be attracted by bright-colored images carved out of wood hanging from the rafters of the dwelling. It was said by Bourke that these objects, after having done duty as idols, were used as dolls; but it is now known, as elsewhere pointed out, that they were made for dolls and presented to the little girls at the great spring festival called the Powamû. They are, however, made and decorated with symbolic designs to represent the different clan ancients or Katcinas, and now they serve to indicate the distinctive symbolism of these beings as elsewhere[4] pointed out in an account of some of their more common forms.

The Hopi idols are distinguished from fetishes or small stone figurines of animals so common in former years. These fetishes appear to be more abundant at the New Mexican pueblo, Zuñi, and are rarely found among the Hopi, where the priesthood of the Bow or Warrior fraternity is less powerful. It is difficult always to determine a line of demarcation between idols and fetishes, but the former are generally larger than the latter and have animal or human forms, being rather family than personal images and more racial in character.

Many of the idols have anthropomorphic and zoomorphic forms among the Hopi. They commonly have a string tied about their necks, to which are attached feathers or personal prayer offerings. These objective prayers or symbolic wishes for blessings are especially common at the winter solstice ceremony.

There is reason to believe that in old times the use of stone idols among the Hopi was very general and that the older the idol the

[3] The kiva of this ruin has a shrine which served also as a fireplace, marked out on its floor, but no idol was found in it. See Explorations and Field Work of the Smithsonian Institution in 1922, Smithsonian Misc. Coll., vol. 74, no. 5, 1923.

[4] Vide "Dolls of the Tusayan Indians," International Archiv., 1893. Of late years there has been a considerable activity in the manufacture of Hopi dolls, stimulated in part by commercial considerations, so that many more kinds are now made than formerly. The work quoted contains only a fraction of the number of different kinds of dolls made as early as 1890.

cruder it was made. They occur in all forms, from simple fossil logs (pl. 1, fig. 2) of petrified wood and waterworn stones to elaborately carved and painted images, human or animal in form, with elaborate symbolism. The more realistic images do not date far back in time, and it is doubtful if many of them antedate the arrival of the Spanish padres. It is not improbable that church santos served as models in their manufacture and may have inspired the elaboration of the more realistic images. The painted stone and wooden slabs bearing symbols of rain clouds, the sun, and various animals, especially those loving water, often forming a reredos for these idols, are here treated as symbols, although there may have been imparted to them something of the same power as to idols. Many of these bear zigzag figures, symbols of lightning, or, in case of wooden sticks, have human heads cut upon one end.

It is difficult to believe that there ever lived any great number of American Indians who worshiped a stone or a wooden or clay image, or any object which they had themselves manufactured. There have been individuals so lacking in intelligence or so sluggish in mentality that they may have been hypnotized into the belief that an idol representing a supernatural being had the power of the god. Some Indians may have confused cause and effect so hopelessly that they ascribed to a waterworn stone the power to bring water or believed that a water-frequenting plant or animal caused rain to fall, but we have yet to learn that psychologically even these people have gone any farther than to ascribe power to such objects. It is quite a different thing to worship the power expressed by certain symbols and the symbol itself. Having exchanged ideas with those who personate supernatural beings in their ceremonies, the author has come to the conclusion that primitive men do not worship idols, but use them as symbols to express by tangible objects well-grounded beliefs current in their philosophy.

A fundamental belief among the Hopi is that men, animals, material objects, sky, earth, fire, water, everything, organic or inorganic, possesses magical powers which are the objective elements of primitive religion. It is believed by most savages that there exists a power beyond that of man which controls the universe and that this power of nature wherever found can be associated with that of man and used by him for material or spiritual advantage. Idols likewise share this power with other objects; by some persons supernatural beings are believed to reside in these images, but few intelligent men believe that the idol is the supernatural it represents.

Worship is not considered the best term to use in speaking of the relation of the powers of supernatural beings and man, but it is the effort of man to be in harmony with the power behind nature, and the idea seems to be that man by a union of his own power with that

personified in natural objects may bring about certain greatly needed material help.

One of the perplexing aspects of the study of individual idols is the multiplicity of names which many of them bear. This has been commented on by many authors and may be due to the composite nature of the Hopi people, different groups of people among a composite tribe like the Hopi having different names for the same god.

Many facts seem to indicate that the Hopi hold a belief in a future existence beyond the grave, which antedates the advent of Europeans. The belief that on death the Hopi descend to the underworld is very old. The breath body or spirit is supposed to lead a life in this place not greatly unlike that on earth. The defunct preserved its kinship with the living members of the same clan and held communication through an opening in the floor of the kiva with those members of the clan that remained behind.

The ancestors of Pueblos, whether cliff dwellers or inhabitants of stone houses in the open, were accustomed to deposit bowls of food and jars of water, ornaments, effigies, and other objects at the graves of the dead, as is generally done by people who believe in a future life. The spirit food is supposed to be consumed by the spirit before its departure for the underworld. The material food decays or is consumed by animals.

In considering any tribe of men among whom idols exist we are continually meeting a great predominance of symbolism. It would seem that a primitive religion dealing with belief, generally symbolizes its conceptions by means of material objects—images, pictures, and concrete representations of other kinds. The relation of the object to the belief is variously stated. For instance, the belief is current that the image is the home or the residence, the place of abode, of an essence or breath body. In more refined civilization this breath body is given the name spirit. It must be remembered, however, that the term spirit originated at the dawn of language and simply meant a breath, having the same material existence as air in the mind of primitive men. In the course of development of men's interpretation of this breath power it has taken on several phases, implying as many differences in meaning. The spirit is sometimes spoken of as a double, and in the Hopi conception every individual has a double, or what might be called a power to accomplish results, or what we would call a vital force, and a mortal body that dies and disappears. The Hopi shaman holds to a belief that by certain incantations, prayers, songs, and association of material objects a magic power that can be used to influence the spirits of other objects can be intensified; for instance, by the use of certain words addressed to certain symbols representing the rain clouds a priest can compel the rain clouds to bring the rain. It is not exactly a response to a petition, but rather a compelling of magic power to act by the use

of a higher and more potent magic in order to accomplish the desired end. Religion among primitive men may be regarded from the point of view of symbolism, and in order to use this effectively they are accustomed to present the powers of nature by symbolic means, representing them either in the form of figures or as engraved images to which the name idol is commonly given. An idol, in other words, is an image made of wood, clay, or stone, in the form of a human or animal shape, supposed from its antiquity, form, or symbolism to possess the power of the god it represents and capable of being used for the bringing about of desired results.

Formerly it was not unusual to see a stone image or idol in every Pueblo dwelling room. This domestic idol (pl. 2, fig. 2) was often of crude construction, in the form of an animalistic or anthropomorphic being. In the house of Intiwa, the Katcina chief,[5] there formerly stood a stone idol of the war god, and there was an idol of the mountain lion in the house of the Sun priest. At the present time there are few of these domestic idols remaining, for zealous collectors from eastern museums have purchased them or they have been hidden away by the owners in some remote corner of the household. Formerly these idols were not only at times sprinkled with prayer meal but also daily worshiped by the members of the household and prayer feathers tied around their necks. Food was generally found clinging to their lips, indicating that there survived into modern times the custom of feeding them which was practiced before the coming of the whites.

Idols in shrines.—The idols found in shrines near Walpi are generally more archaic than those used on altars in kivas and are made of stone, rarely of wood and clay. They are sometimes simply strangely formed waterworn stones, more like fetishes.

There is a well-made idol near the stairway trail on the east side of the mesa, which is called *Talatumsi* (the Elder Sister of the Dawn, planet Venus). This shrine is a rude excavation made by man in a bowlder, its opening being closed by a flat slab of rock that serves as a door, which is ordinarily luted in place with clay. This door is removed in November every fourth year, when the idol in the shrine is taken out and carried, with considerable ceremony, to the top of the mesa; here it is placed on the kiva hatches and rites performed near it. This idol of Talatumsi is a wooden image dressed in a white ceremonial blanket, with an embroidered sash about her waist, in which are put the wooden prayer offerings that are every four years made to her (pl. 2, fig. 1). At the close of rites around the kiva entrance the image is carried back to her shrine and the door luted in place, awaiting the next quadrennial emergence. As this image is very sacred, it is rarely exhibited, and no one save the initiated is supposed to be acquainted with her shrine.

[5] When the author last visited Walpi this house was deserted and falling into ruins.

3

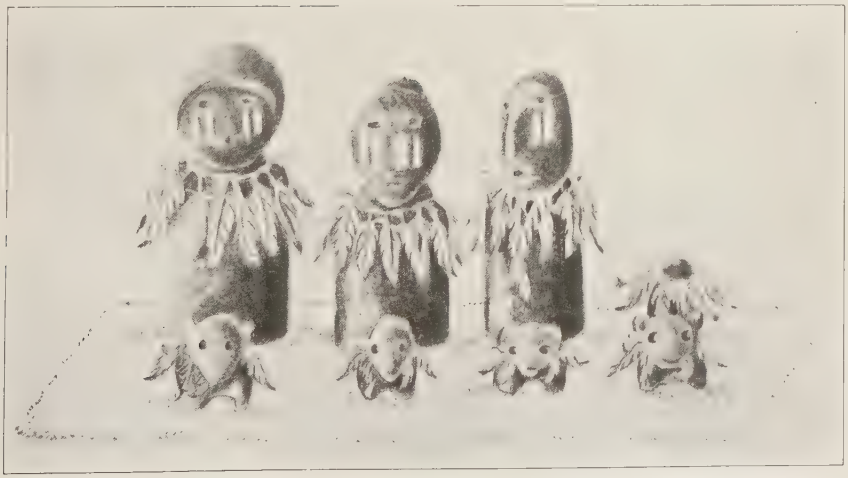
1. SHRINE OF THE SUN NEAR WALPI. THE STICKS WITH PRAYER FEATHERS ARE MADE IN GREAT NUMBERS AT THE WINTER SOLSTICE CEREMONY AND ARE OFFERINGS TO THE SUN FOR INCREASE OF ALL BLESSINGS DESIRED BY THE HOPI.
2. SHRINE WITH FOSSIL LOG. VISITED AT THE NEW FIRE CEREMONY AT WALPI. ON LEFT OF THE TRAIL FROM EAST TO MIDDLE MESA.
3. SHRINE OF THE FIRE GOD MASAUWU, SITUATED IN THE PLAIN WEST OF WALPI. MEN RETURNING WITH FAGOTS ON THEIR BACKS THROW A BOUGH ON THIS SHRINE. SMALL POTTERY DISHES ALSO DEPOSITED IN IT.

3

4

1. IDOL OF TALATUMSI REMOVED FROM HER SHRINE AT THE QUADRENNIAL CELEBRATION OF THE NEW FIRE AND CARRIED TO THE TOP OF THE EAST MESA BY HER GUARDIANS, THE HORN PRIESTS.
2. HOUSE IDOL OF MOUNTAIN LION.
3. IDOL OF THE GERM GOD, MUYINWÛ. (SQUARE TOWER HOUSE,)
4. SIDE VIEW OF STONE IDOL OF PLUMED SERPENT (PIPE SHRINE HOUSE).

1. THE STONE IDOL OF THE TWISTER, USED IN THE MARAU CEREMONY AT AWATOBI, NOW A RUIN NEAR WALPI.



2. STONE IDOLS ON THE WARRIOR ALTAR AT HANO. THE THREE LARGER REPRESENT THE LITTLE GODS OF WAR; THE SMALLER ON THE RIGHT OF THE REAR ROW, THE SPIDER WOMAN, THEIR MOTHER. THE FOUR STONE IDOLS IN THE FRONT ROW ARE ANIMAL PETS OF THE IDOLS.

1

2

3

4

1, 2. FRONT AND SIDE VIEW OF A STONE BIRD IDOL, PIPE SHRINE HOUSE.
3. STONE IDOL OF PLUMED SNAKE. SAME SPECIMEN AS PL. 2, FIG. 4; FRONT VIEW WITH FEATHERS RESTORED. PIPE SHRINE HOUSE.
4. STONE HEAD OF MOUNTAIN SHEEP, PIPE SHRINE HOUSE.

Talatumsi is related to one of two wooden idols called Alosaka (germ god) that were formerly worshiped by the inhabitants of Awatobi. Up to the year 1888 these stood in a little cave under the rim rock at that ruin and, although the pueblo was deserted in 1700, were objects of reverence; but on that year Navajos, not knowing that these images were still used by the Hopi, desecrated their shrine, carried away the idols, and sold them to Mr. Thomas Keam, who deposited them in his store in Keams Canyon, some 8 miles away. When the Hopi of the Middle Mesa heard of this act they appeared in force at the store, demanding the idols, which they held in great reverence. Mr. Keam, being a man of broad appreciation, delivered the images to the chiefs of the Middle Mesa, who made a broad trail of meal, reaching from his house to the Middle Mesa, over which the idols were carried to a new shrine near the village, where they are now kept in a small cave.

Before the coming of the white people there were several other shrines situated near by or a considerable distance from the pueblos, but of late all have been brought nearer the village in order to protect them from desecration by alien people, who have rifled many shrines for commercial purposes.[6]

A shrine in which were formerly kept the effigies of the Great Serpent is one of those which have been moved nearer to the mesa, and the serpent effigies when used are taken from their present receptacle, although in commemoration of their past history an offering is made and prayers are annually said at their original home.

A coiled or screw-like idol (pl. 3, fig. 1), called a "heart twister," occupies the central position in a line of images before the reredos of the altar of one of the basket dances. It is said by the Hopi shamans that in certain diseases the heart is twisted out of position, and by waving this object in a circle over the head of the sufferer the heart can be restored to its natural position.

These idols are known as "twisters" (pl. 3, fig. 1), one of which, found not far from the prehistoric pueblo, Awatobi, is now in the Ethnological Museum at Berlin, Germany. This idol is like a stone screw, about 1½ feet high. Around it is a spiral groove; white, red, and green bands run around it like stripes of the same colors on a barber's pole. This idol was probably used for the same purpose as the so-called "heart twister" on a modern Hopi altar, which legends declare a priestess saved in the massacre and introduced into Walpi from Awatobi, near which ill-fated pueblo this idol was found. On the wagon trail to Hano there is another of these "twisters," a coiled cast of a cephalopod shell that has for years stood in a shrine or rude cairn not far from the road, halfway to the top of the mesa from the plain.

[6] The desecration of the Hopi shrines and abstraction of their idols have been much resented by the priests.

While the author was studying the rituals of the Hopi Indians he rented a room in Hano in which, unbeknown to him, the serpent effigies were kept. At one end of this room there was a raised banquette admirably adapted for a sleeping place, and upon it he spread his sheepskins and blankets and for months slept nightly upon it. On the opening night of the March drama, when the time came to procure the serpent effigies, a procession, headed by the chief, went to the room occupied by the writer and the priests began to scrape away the clay on top of the bench and brought to light four vases covered with a circular stone covering. In the vases were kept the serpent effigies, and unknowingly the author had slept on snake idols for several months without harm. Having procured the serpent effigies, the priests carried them to the Sun spring at the foot of the mesa and several weird rites, as yet never described, were performed about them. Formerly the idols of the horned serpent were kept in a cave some distance north of Hano, but that shrine was abandoned on

FIG. 1.—Side and front views of Plumed Serpent idol. Far View House, Mesa Verde National Park.

account of its exposure to persons of vandalistic tendencies. It is instructive to note that when a shrine has once been used as the receptacle for an idol and the idol removed, the priests do not neglect to say their prayers at the ancestral place. This feeling appears in another form when ancestral springs are visited for sacred water for ceremonials. For instance, in the snake dance priests go to old springs in the north for sacred water because when they lived in the cliffs the adjacent springs were used by them for sacred purposes.

In the work of excavation of Mesa Verde ruins last year (1922) stone idols of animals were discovered in shrines near Pipe Shrine House. These are crude images and considerably broken, but they are not unlike modern counterparts. One of the largest, the torso of the mountain lion[7] above mentioned, found in an inclosure south of Pipe Shrine House, was left in place in the south shrine of this remarkable building. The head of an idol recalling the Great Serpent (pl. 2, fig. 4), likewise broken, was discovered at this ruin. Although attached feathers were absent, there is a groove around the neck of this idol where feathered strings were probably once tied.

[7] At Walpi, Hopi women sometimes wear a small stone fetish of a mountain lion attached to their belt.

It is worthy of mention that the Great Serpent figured in the Mesa Verde rituals, for set in the wall between the two doors in the south wall of Pipe Shrine House there is an inscribed rock on which is an incomplete spiral identified as the pictograph of the serpent, indicating that the worship of the Sun Serpent God was one of the purposes of that building. The snake idol shown in figure 1 was found near Far View House.

A bird idol (pl. 4, figs. 1 and 2) and a stone head identified as the head of the mountain sheep were likewise found in the dump removed from Pipe Shrine House, but the positions of the shrines which once housed these supernaturals were not discovered. The stone head of a mountain sheep idol (pl. 4, fig. 4) was found in the dump outside Pipe Shrine House on the Mesa Verde National Park. It appears that a larger number of stone idols were discovered in the excavations at Pipe Shrine House than in any other Mesa Verde ruin, and that they not only far outnumber those from any other ruin on the park but also in the San Juan Valley. No stone idols have yet been found in Mesa Verde cliff houses, as the shrines of the cliff dwellings are yet to be discovered.

Idols on altars.—The majority of idols are found on altars, and in order to get a better idea of their forms we will now consider a few of the great Hopi altars. These idols are often more elaborately made than those found in shrines and are generally of wood, or when very ancient are of stone.

The distribution of idols[8] on Hopi altars is somewhat as follows:

Ceremony.	Idols.
1. New Fire Ceremony	1. Talatumsi, Alosaka, anthropomorphic idol of Germ God; (Elder Sister of the Dawn; the Morning Star, Warrior God.)
	2. Tuwapoñtumci. (Earth Altar Woman)
2. Winter Solstice	Germ God (stone cone).
	Plumed Serpent. (Effigy).
3. Momtcita	Püükong, War God.
	Kokyanwüqti, Spider Woman.
	Stone images of animals.
4. Powamû	Sun sand picture.
	Tungwup.
5. Palulukon	Plumed Snake. (Effigy).
6. Snake Dance	Human personations of snake maid and youth.
	Animal idols.
7. Flute	Images of Flute hero and Flute maid.
	Sky God, Germ God, birds.
8. Lalakonti 9. Owakülti	Cultus hero and heroine, anthropomorphic idols.
10. Mamzrauti	Germ God (Muyinwu). Stone cone.

[8] There are several other idols in use at Walpi which are not included in this list.

The Oraibi Snake altar has two idols, differing from that at Walpi and the other Hopi pueblos. The rites about it have never been observed.[9]

The idols used by the Warrior priesthoods at Hano and Walpi are set up directly after the winter solstice ceremony and consist of shapely stone images of Spider Woman and her two offsprings, the Twin Gods of War (pl. 3, fig. 2). When not used these idols are in the keeping of the priesthood of the Bow, and the ceremony in which they are used is called the Momtcita.[10]

The secret rites of the Hopi priests are generally conducted in special rooms called kivas, of which there are five in Walpi. Modern kivas are generally situated in the courts separated from secular rooms, but several priesthoods use special rooms, not known as kivas, for ceremonials. These rooms are embedded in the house masses, generally the rooms of the clan that owns the idols, fetishes, or ceremonial paraphernalia of that family. For instance, the Flute room, where the Flute idols are kept and in which the Flute altar is erected, is a good example of such a type of ceremonial room. The chamber in which the Sun priests gather and erect their simple altar is another instance of a ceremonial room not a kiva. A third example of a chamber not a kiva is that in which the Warriors or Priesthood of the Bow annually assemble and hold their sacred gatherings. This room is seldom opened except on days of war rites, and idols are hidden in a recess in its walls. Here they are kept, and in midwinter they are taken from their receptacle and arranged as an altar.

This room (fig. 2) of the Warriors is situated in the second story of Walpi directly under the dwelling of the Pakab or Reed people, the chief of which inherited the tiponi or badge of office of the Warriors. It is entered by a hatchway and is without windows. It is rectangular in shape and the niche or sealed recess where the idols and other paraphernalia of the Warriors are customarily kept in its northeast corner. The length of this room is about double the width and its walls are oriented about east and west. The wall decoration of this chamber is interesting, corresponding with its use. Each wall is painted with a picture of a different animal characteristic of a cardinal point, and as these animals are realistic enough for identification we may conclude what animals are associated with the cardinal points.

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[9] A description of this altar by Voth was mainly derived from the author's description of the Snake altar of the Walpi ceremony. The view of the sand picture of the Snake altar at Oraibi by the same author is made from the Walpi altar, not from direct observation.

[10] The ceremonies are described in the author's article, "Hopi Minor Ceremonials," Amer. Anth., n. s., vol. v, no. iv.

On the north wall, facing west, there is a picture of the mountain lion, 3 feet long, of brown color. The eye of this animal is a glistening fragment of a pearly Haliotis shell; a line painted red represents the life line, extending from the mouth to the region of the heart. The tail extends forward above the back, a significant position in pictures of the mountain lion, the tail of which is generally represented as a ridge in relief extending longitudinally along the backbone; but in this connection it is instructive to call to mind

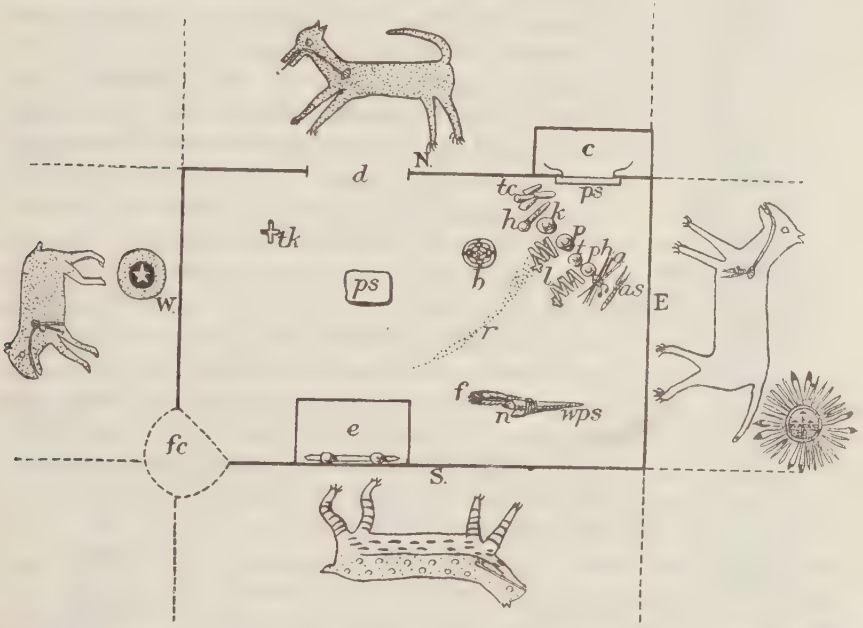

FIG. 2.—Diagram of Warrior room at Walpi; inner rectangle, floor of room; animals painted on walls. N. W. S. E. cardinal points; north, west, south, east: *as*, Aspergil; *b*, basket plaque; *c*, niche in which idols are kept, closed by stone paint slab (*ps*), on which paint is ground; *d*, door into next room; *e*, entrance to room from roof by ladder; *f*, eagle feather; *fc*, fireplace; *h*, ancient war club; *k*, spider woman idol; *l*, lightning framework; *n*, packet of prayer meal tied to prayer stick (*wps*); *p*, little war god; *ph*, little war god; *ps*, stone paint slab used as door to niche (*c*); *r*, pathway of blessings; *t*, Tiponi (warrior badge of office); *tc*, ancestral celts; *tk*, wooden cross, *tokpela*, representing sky god; *wps*, warrior prayer stick.

that the large so-called stone lions at Cochiti pueblo do not have the tail extended along the median dorsal line.

The figure painted on the east wall measures about 3 feet long and has an extended tail, just above which is a conventional sun symbol consisting of a circle from which radiate eight feathers arranged in four clusters of two each and intermediate lines representing the rays of the sun. The figure on the south wall represents the wild cat and that on the west a bear drawn above a five-pointed star.

The idols on the altars used by the Warrior priesthood at Walpi and Hano are practically representative of the same supernatural

beings, viz, the Spider Woman and her children, the Twin War Gods, and certain "pets" associated with them. These are represented in the accompanying figure (pl. 3, fig. 2) of the altar at Hano.

The most important idol of the Hopi is that of the Sun god, known in ceremonials as the Heart of the Sky. One of the best examples of this god, found on the Oraibi Flute altar, elsewhere figured,[11] should be especially mentioned, as it is the best Hopi idol. A symbol of this god, which takes the shape of a cross, occurs on several of the Hopi altars.

FIG. 3.—Idol of the Germ God, Muyinwû. From the altar of Mamzrauti ceremony.

Next in importance to the idol of the Sky god is that of Muyinwu, the Corn Mountain or Germ Goddess, which occupies a prominent place on the majority of Hopi altars. Its archaic form is a conical stone or wooden object called the corn hill or corn mound (pl. 2, fig. 3, and text fig. 3).

The altars of the Hopi Basket Dances have two idols (figs. 4 and 5), one of the cultus hero and another of the cultus heroine, parents of the clan that controls the rite. The latter strongly resembles Calakomana or the Corn Maid as she appears in the Tablet Dance, when she is called the Palahikomana. Similar pictures of the same personages, having human heads, and wings, bodies, and tails of birds, also occur on the lateral wings of the altar reredos.

Among the instructive sacred objects on the Lakone altar are bundles of rods that are placed over a sand mosaic and are spoken of as Germ God idols. These bundles contain prayer sticks and other fetishes,[12] and although described as idols, suggest the bundles of the plains tribes. They are regarded as very sacred objects, being sometimes sprinkled with sacred meal; it is commonly said that they represent "mothers," and they are held in great respect.

FIG. 4. — Idol of Marau Maid from Marau altar.

The Hopi dances, commonly called Katcinas, in which masked men representing ancients appear, have idols on the altars which are erected at the advent and departure of these beings, Powamû and Niman. One of these idols is called Tungwup (the sun); the other Pokema or Eototo, the earth god.

On several altars, as that of the Antelope in the snake dance, we find stone idols in the form of animals, which are rude and small, indicating a more archaic condition than the elaborate wooden figurines.

[11] Sun Worship of the Hopi Indians, Annual Report of the Smithsonian Institution, 1918.

[12] The contents of one of these bundles are enumerated in the author's account of the Lakone altar, Amer. Anth., 1892.

The author has already alluded to the idols on the altars of the Flute priests in his article on Sun Worship.[12] The Flute altars have anthropomorphic images representing the Flute Youth and Maid, as well as the Germ idol. The former are shown in the accompanying figure (pl. 5), one representing the Flute Youth, the other the Flute Maid. Wooden images of birds are frequently found on Hopi altars and likewise occur in ruins situated along the San Juan River.

Traces of sun worship in the numerous rites of the Flute ceremony are many and highly significant, emphasizing the tradition that the Flute people, like the Patki or Raincloud clans, came from the south and joined the Snake and other northern clans in prehistoric times. Later the Flute clans separated from the northern clans, to be reunited at Walpi, where they have since lived in harmony, forming a homogeneous people. The Flute legends have many similarities to those of the Snake fraternity, which leads to the belief that they lived some time together.[13]

FIG. 5.—Idol of the Germ God, Muyinwû. From wing of the reredos of Marau altar.

Winter solstice altar (Hano).—The most striking idol used in the winter solstice ceremonial is an effigy of the Plumed Serpent, which is also used in the spring equinoctial ceremony. This has already been described and figured in the author's pamphlet on Sun Worship of the Hopi Indians. These idols are effigies manufactured from various materials. At every celebration of the vernal equinox and winter solstice they are mended, repainted, and adorned with fresh feathers.

One of the most archaic rites performed in the vernal equinox ceremony in March is the visit made by the guardians of these snakes to the Sun Spring, their home or shrine. They are laid on the bank of this spring with their heads reaching to the water, into which their tongues hang, and prayers are said to them before they are carried into the kivas.

Idols are not necessarily made of stone, clay, or wood, but may be effigies constructed of other materials. Each of these idols in the Walpi variant of the winter solstice ceremony is an effigy composed of a series of hoops over which is tied a buckskin or cloth cover representing the body of a serpent, while the head is made of a painted gourd, the whole decorated with symbolic markings.

[12] The contents of one of these bundles are enumerated in the author's account of the Lakone altar, Amer. Anth., 1892.

[13] There is a ruin north of Walpi, said to have been their former habitation, called Leñanobi, the House of the Flutes.

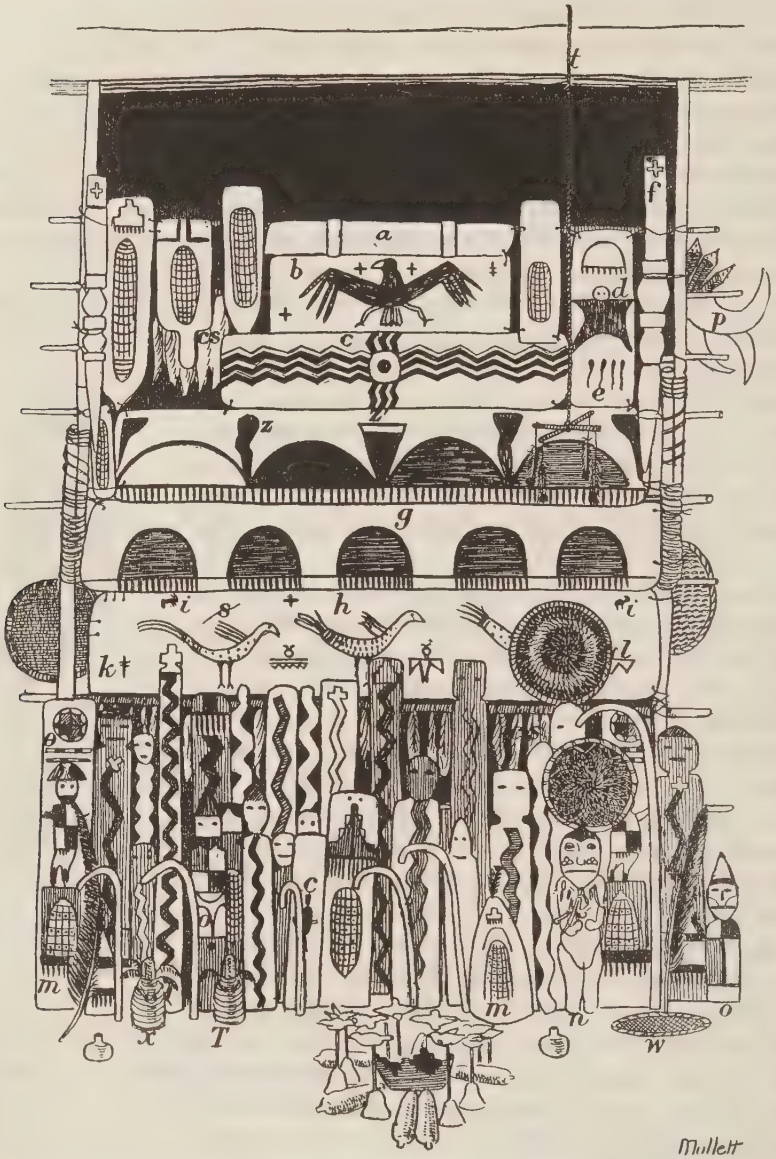

FIG. 6.—Altar of the Basket Dance, Owakülti, at Sitcomovi. This altar was erected in a kiva and consists largely of slats of wood decorated with symbols (*w*), tied together and held in place by upright and horizontal rods. Individual cult objects designated by the following letters: *a*, Sky band; *b*, Eagle of the Sun; *c*, Upper Sun with lightning; Lower Sun with rays of the four world quarters; *cs*, Corn symbol; *d*, Frog; *e*, Tadpoles; *f*, Star symbol; *g*, Rain clouds; *h*, Unknown birds; *i*, Rabbit; *k*, Dragon fly; *l*, Butterfly symbol; *m*, Germ God in form of corn mound; *n*, Germ Goddess; *o*, Little War God; *p*, Horns worn on head of Owakül Maid; *T*, Tiponi, badge of chief; *t*, Tokpela, sky god; *w*, Netted disk carried in hand of Owakül Maid; *x*, Tiponi, badge of chief; *z*, Lightning.

Through the middle of the body is a stick, called the backbone, by which the effigy is manipulated. This effigy is regarded by the priests in much the same way as a stone idol, prayers being offered to it with sacred meal in a similar way.

The Hano priests, however, in their winter solstice rite make each year a clay idol of the Plumed Serpent, *Avanyu*,[14] which is laid on the floor back of their altar. A somewhat similar idol of stone (pl. 2, fig. 4; pl. 4, fig. 3; and text fig. 1), found at the Pipe Shrine House, Mesa Verde, was probably the recipient of prayers in the same way as the clay images of the Hano Winter Solstice altar and the effigy idol of the Walpi or Hopi variant.

Unworked stones of rare forms, fossils, or stones eroded by water, may also serve as idols, and we find them treated as such; for instance, a fossil log in a shrine near Walpi is used in the New Fire ceremony. The author found many and various waterworn stones, crystals, and Tertiary fossil shells in the shrines of Pipe Shrine House. There exists a rich chapter of folklore regarding the efficacy of strangely formed stones among the Hopi, which is not here considered lest it would swell this article to undue proportions.

The most widely known of all Hopi ceremonies is that called the Snake Dance, in which there are two altars. Neither of these has an anthropomorphic idol representing the cultus hero and heroine of the Snake-Antelope, but at the Antelope altar these ancestral supernaturals are personated by a boy and girl who stand back of the altar, as shown in plate 6. On the rear border of the sand picture that forms the greater part of this altar are a mountain lion fetish and several stone images of animals.

The related Flute ceremony has its altar idols (pl. 5) representing the Flute Hero and Heroine carved out of wood. In the march from the Sun Spring to the top of the mesa they are represented by a boy and two girls appareled like the Snake Maid and Antelope Youth of the Antelope altar (pl. 6).

Cultus heroes and heroines are represented by wooden idols in the altars of the three great basket and tablet dances, known as the Lalakonti, Mamzrauti, and Owakülti. They are well fashioned and suggest recent manufacture, or later than those of stone used in the more archaic New Fire and Winter Solstice ceremonies.

In the accompanying illustration (pl. 6) the Antelope priests are represented as seated around the Antelope altar in a secret consecration of prayer sticks of the celebrated Snake Dance at Walpi. Although many hundred white people have witnessed the open Snake Dance, thus far only a very few have been admitted to the rites that take

[14] A description of this idol may be found in Hopi Minor Ceremonials, Amer. Anth., Vol. IV, n. s.

EXPLANATION OF PLATE 5 (BLUE FLUTE ALTAR).

a, Flute Youth.
b, Flute Maid.
c, Flute Tiponi, badge of chieftain.
d, Flute birds.
e, Medicine bowl.
fc, Flute chief.
g, Mounds of sand, inserted in which are wooden "corn flowers."
h, Four marks on each wall of the room made with corn (prayer meal).
i, Bank of corn ears behind altar.
m, Corn ears.
n, Basket tray.
o, Wooden slat representing lightning.
p, Prayer sticks and corn husks.
q, Rafter of house roof.
r, Gourd rattle.
rc, Rain clouds, square and semicircular.
s, Slab of stone on which paint is ground.
t, Ladle made of gourd.
u, Blanket.
v, Hanging strings (rain?).
w, Feathers, blankets, bags, and ceremonial paraphernalia.
x, Cupboard.
z, Shelves.

Feather symbols indicated by triangles on angles of the rectangular rain clouds.

BLUE FLUTE ALTAR AT MICONINOVI, MIDDLE MESA.

place in the kivas or secret rooms at that time, and one may count on the fingers of one hand the descriptions of these rites of the Snake Dance that have been published. This illustration (pl. 6) has been made with care and accuracy to show the character of the altar and the posture of the priests gathered about to begin the dramatization and sing the 16 songs in the Walpi presentation. Having witnessed this rite in the five Hopi villages that celebrate the Snake rite, the author does not hesitate to say that the Walpi variant is one of the best in Hopi land.[15]

The earliest account of this altar and the songs about it appeared in the author's Snake Ceremonies at Walpi in 1894,[16] based on a study of the Snake Dance at Walpi in 1891 and 1893. An accurate picture of the sand mosaic in color appeared in the year 1900.[17]

Let us briefly consider this rite. It is called the consecration of certain prayer emblems and is a rude dramatization of a rite mentioned in the Hopi Snake legend. The ceremony is supposed to have formerly been celebrated by the ancestors of the Snake people in the underworld, and to have been brought to the surface of the earth by a cultus hero known as the Antelope Youth. This youth, or cultus hero, visited the underworld where he married a daughter of the chief, and representations of him and his bride are standing back of the altar. The exact time in the rite chosen for illustration is midway in the songs when the pipe is passed to the Antelope Chief, Wiki,[18] the signal for the beginning of the ceremony.

A large stone idol of the mountain lion stands on this altar back of the sand picture between two palladia or tiponis, one of which is now in place; the other is held on the left arm of the Antelope or Snake Hero. There are several smaller idols on the altar which are said to be heirlooms inherited from very old times.

Midway in the songs about this altar the chief of the Antelopes receives from the pipe lighter a lighted pipe or conical "cloud blower," and kneeling back of the mountain lion so that the pointed end rests between the ears of the idol, blows six whiffs of smoke through the cloud blower upon the sand picture.[19] The ingredients smoked in this cloud blower are herbs gathered from the cardinal points, mixed with fragments of spruce leaves, the burning of which makes a pleasant smell in the room.

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[15] The Walpi Hopi claim that their variant is the most ancient and truthful of all and assert since the original palladium of the Snake priesthood is now in their possession that all others are imitations.

[16] Journal of Am. Ethn. and Arch., vol. IV, Boston, 1894.

[17] Tusayan Flute and Snake Ceremonial, 19th Ann. Rept. Bur. Amer. Ethn., 1900.

[18] The rites, songs, and prayers at the consecration of the prayer emblems on this altar are described in Vol. IV A, Journal of Am. Ethn. and Arch., Boston, 1894.

[19] This and other straight-tubed pipes are known as cloud blowers. There are all gradations in form from a tobacco pipe with upturned bowl to a straight-tubed cloud blower

EXPLANATION OF PLATE 6.

A, Wiki, Antelope chief.
B, Kopeli, Snake chief.
C, Antelope ´Snake) Maid.
D, Antelope (Snake) Boy.
E, Hahauwe, Smoke Chief.
F, Kakapti, Sand Chief.
G–Q, Antelope priests.
R–T, Snake priests.
a, Aspergill.
at, Antelope tiponi.
b, Tobacco pouch.
c, Corn stalks.
d, Tray of prayer meal.
f, Basket for prayer sticks.
g, Water gourd.
h, Butterfly-maid stone.
i, Clay pedestals.
j, Crooks (ceremonial bows).
k, Fireplace.
l, Ceremonial arrow.
m, Medicine bowl.
ng, Armlets.
o, Fetish of mountain lion.
p, King crab (*Limulus polyphemus*).
r, Rattles of Antelope priests.
st, Snake tiponi.
t, Tcamahia.
nrc, North rain-cloud figure.
src, South rain-cloud figure.
wrc, West rain-cloud figure.
erc, East rain-cloud figure.
nl, North lightning-snake figure.
wl, West lightning-snake figure.
sl, South lightning-snake figure.
el, East lightning-snake figure.
ng, North gate.
eg, East gate.
sg, South gate.
hd, Bunch of feathers worn by an Antelope priest.

ANTELOPE ALTAR OF THE HOPI SNAKE DANCE.

Interior of a Kiva at Walpi showing Antelope Priests Consecrating Prayer Offerings.

FOR EXPLANATION SEE PAGE 394.

This cloud of smoke, by sympathetic magic, is supposed by the priests to represent the raincloud, and the production of the smoke is one way of praying for rain that is often sorely needed for the parched fields of the Hopi. As the formal cloud blowing in the secret rites of the Antelope altar takes place midway in the progress of the songs it may be regarded as the culmination of the ceremony. The presence of the mountain lion idol is appropriate, because this fetish represents the Mountain Lion people, who formerly lived with the Hopi in their cliff houses on the San Juan.

One object that may be called a fetish is omitted in the picture of the Antelope altar. In the 1893 Snake Dance at Walpi the author gave Wiki, the Antelope priest, a specimen of the King crab (*Limulus polyphemus*) which he collected on the Atlantic coast. The Antelope chief had never seen a horseshoe crab and did not know what it was. After he and his fellow chiefs had examined it one of their number pronounced it a "Giant Tadpole" and placed it on the altar, after which all the priests sprinkled it with meal and prayed to it, as they believed it efficacious to bring rain. In other words, it was accepted as an idol,[20] although probably no one had ever seen one of these animals.

It will be noticed that the Antelope altar is largely horizontally placed, consisting of a sand picture and accompanying objects, none of which rise high above the floor. The only upright portion of this altar is a stone slab known as the Butterfly Maid,[21] which stands back of the altar, making a very ancient form of reredos.

Prayers to idols.—The method of praying adopted by the Hopi is practically identical for all idols. When an altar is set up it is customary for a devout priest on entering the kiva to ask the chief, as he steps from the ladder, whether he is welcome or not, and, on being informed that he is, he approaches the altar with the fireplace always on his left hand. He then takes a little prayer meal from the flat basket tray on the floor, and, after raising it to his mouth and praying, sprinkles it upon the idols and other altar objects.[22] The breath body of the prayer meal is supposed to communicate the wish of the worshiper to the god represented by the idol. When a priesthood prays as a body, or when an individual priest offers a more formal prayer in the form of a prayer stick, it is inserted in the girdle about the body of the idol. These prayer sticks are generally placed in a ridge of sand before the image. Another method of prayer is by the use of a stringed

[20] The last time the author saw the Antelope altar this animal was still in use.

[21] The Butterfly clan is associated with Badger, Butterfly, and kindred families, who are said to have been among the latest introductions into the Hopi country.

[22] Under prayers may be mentioned smoking tobacco fumes upon idols or asperging medicine over them, both of which are regarded as symbolic rain prayers.

feather, which is breathed upon and tied either about the neck or attached to the belt of an idol.

The mouths of domestic idols have fragments of food adhering to their lips, showing it was customary to offer nourishment or to feed them; but the habit of feeding Hopi idols is not now as common as formerly. It is true that there are very few idols now standing in the corners of living rooms, although in 1890 the author knew of several of these household images, which have gone the way of many other Hopi specimens; the museum collector has purchased and carried them off, thus transporting them from their natural environment to beautiful cases where they are exhibited, often without explanations of their significance.

Conclusions.—Do the preceding pages have any bearing on the questions so frequently asked: Who were the Hopi and whence did they originate? Does the character of their idols throw any light on Hopi history before they were discovered by Tobar in 1540?

On comparison of the simplest form of stone idols here considered with those from ruins along the San Juan River and its tributaries we find the resemblance close, almost identical; but we also find some of them have a close likeness to idols found in ruins south and east of the present site of Walpi. The difference in form of the idols can be in part explained by age but mainly from their geographical derivation. In this connection it is to be noted that the priesthoods that own these idols and control the rites about them claim they are related to clans that declare they migrated from the region inhabited by people that have closely related idols. In other words, archeology affords strong evidence of derivation of cult objects used in the religious system of the Hopi from different directions, thus supporting their migration legends. Relations of idols can be used to identify former homes of the separate components of the Walpi population. They furnish evidence that the Hopi are a composite race or that the population of Walpi is a blend or mixture of peoples that came to the East Mesa from different directions, as shown in an article on Tusayan Migration published elsewhere.[23]

The forms, decorations, and material from which idols are manufactured, like secular portable utensils and implements, can be used by the archeologist as data bearing on prehistoric migrations of groups of Indians. One of the last objects an Indian priest would throw away as he migrated from place to place would be his idols. Other things he might leave behind, but his gods, never. So attached is he to localities once his home that he has often taken the trails back; he often visits ancestral springs to get water for religious pur-

[23] 19th Ann. Rept. Bur. Amer. Ethn.

poses; his idols he carries with him. The technique of these idols varies in different clans and furnishes important data in studies of clan migration.

In conclusion, it may be said that it is very difficult to accurately define the line of demarcation in the Hopi mind between what would ordinarily be called an idol and other sacred or cult material objects used in worship. We ordinarily confuse the terms fetish and idol but the latter generally has some anthropomorphic or zoomorphic form. The Hopi Snake Dance and attendant secret rites are regarded as the oldest in the ritual, a conclusion that comes out clearly in the archaic conditions of the altar and the character of objects on it. The Antelope altar is conspicuous by the absence of idols, whereas other great nine-days' ceremonies of the Hopi have well made wooden anthropomorphic images in addition to graven representations of nature power, sun gods, germ gods, and the like. These graven idols indicate a late cultus, pointing to a more recent development. But it is instructive to notice, in passing, that on the Antelope Snake altar the cult ancestors are represented by a boy and girl, indicating that, in this instance, the ancient way of representing the cult ancestors appears not to be by idols but by human beings personating them; on the other hand the idols on the Flute altars are so well made that they appear to be carved out with iron implements. In most respects, and especially traditionally, the Snake and Flute clans are related. The explanation would naturally be that the resemblances are due to a former life of the two clans together. It may be stated as a general law that in the composition of the Hopis those clans that came from the South had a much more complicated ritual and much more elaborate symbolism depicted on their idols than clans from the North or those that originally inhabited the cliff houses. The Hopi are the survivors of a prehistoric people on the line of fusion of two forms of culture, the pure pueblo of northern origin and the now kiva people of the Gila or the South. The earliest contact was practically along the Little Colorado valley, where the mixed population survived into historic times and whose best present survival is the well-known pueblo, Zuñi. Lower down the Little Colorado, the settlements were abandoned and their populations migrated northward and joined the kiva people or pure pueblos, and the mixture still survives as the Hopi Indians of Arizona.

TWO CHACO CANYON PIT HOUSES.[1]

By Neil M. Judd,
Curator, American Archeology, U. S. National Museum.

[With 7 plates.]

In writing or speaking of the prehistoric habitations of Chaco Canyon[2] one invariably has in mind only the great communal dwellings, such as Pueblo Bonito and Pueblo del Arroyo. This mental discrimination is the natural one, for these ruins of stone-walled, terraced villages are among the best preserved and most impressive of all the ancient structures north of Mexico. They immediately arrest the attention; they convey, in comparison, so colorful a picture of the busy life once carried on within their now silent rooms that the remains of contemporaneous, or even more ancient, settlements near by are usually entirely disregarded.

Lesser house remains, however, exist in large numbers in Chaco Canyon. There are talus pueblos and a few small cliff dwellings at or near the base of the perpendicular cliffs which form the north wall of the canyon; there are literally hundreds of small ruins scattered along the south side of the valley and out in the broad reaches of open country that stretch away from its inclosing mesas. The presence of these latter structures has been known for many years, yet they have received but scant attention from those students of prehistoric cultures who have pursued their investigations in the Chaco Canyon region. In addition to these several types of primitive habitations, two isolated pit houses, vastly more ancient than the stone structures already mentioned, have recently been discov-

[1] Printed with the permission of the National Geographic Society, whose Pueblo Bonito expedition is being directed by Mr. Judd.

[2] That portion of Chaco Canyon most densely inhabited in prehistoric times roughly parallels the boundary between San Juan and McKinley Counties, N. Mex.; the stream course turns northward a few miles to the west of this center of population and joins the San Juan River in the extreme northwestern corner of the State. Eighteen of the major ruins are now included in the Chaco Canyon National Monument, created by presidential proclamation Mar. 11, 1907. The Chaco drainage is semidesert in character, with but little permanent water and few trees except on the higher mesas. Navaho Indians and a half dozen white settlers and traders, with their families, comprise its present inhabitants.

ered and examined by members of the National Geographical Society's Pueblo Bonito Expedition.[3]

PIT HOUSE NO. 1.

The first of these pit houses was encountered in 1920 during trenching operations in a burial mound about 100 yards east of Casa Rinconada, a circular ruin surmounting a low knoll on the south side of Chaco Canyon, opposite Pueblo Bonito. A number of stone-walled ruins, each with its own refuse pile, are to be seen in this vicinity. The pit house was discovered, quite unexpectedly, by Zuñi workmen near the lower edge of one such pile, and the fact that ashy earth had gradually worked from the latter down over the former unquestionably accounts for certain intrusive sherds in the collection (p. 403). The writer was absent on reconnaissance duty while the east half of this primitive dwelling was being excavated, but the Indians subsequently pointed out the approximate spot at which each of the specimens discovered was exposed.

This first pit house (fig. 1) examined by the Pueblo Bonito Expedition averaged 3 feet (0.914 m.) in depth and 17 feet (5.182 m.) in diameter; its walls were vertical except at the south, where they flared outward a few inches (pl. 1, fig. 1). The room had been gouged, presumably with stone or wooden implements, from the clayey silt strata which wind and water had deposited throughout the length and breadth of the valley; its original depth may be preserved in the present walls but the superstructure which covered the pit has long since disappeared. That it had some sort of timbered roof goes without saying. (Two short, decayed fragments of logs were exposed on the west side of the room, standing on the floor and resting against the wall of the excavation.) Lacking definite information to the contrary, it may be assumed that the walls and ceiling of this house were shaped after the fashion of those in the dwelling next to be described. It is not unlikely that what is herein referred to as a wall was, in fact, the face of a bench upon which the roof timbers rested.

No trace of applied plaster was present, but the sides of the excavated chamber had been roughly finished by dampening the clay and pounding it to a hard and relatively smooth surface. The not unsatisfactory results of such treatment may be observed in plate 1, figures 1 and 2. As would be expected in so primitive a habitation, the floor, while hard and compact with use, was noticeably uneven.

In its furnishings, this Chaco Canyon pit dwelling illustrates the simple life and the few needs of its former inhabitants. A cir-

[3] See Smithsonian Misc. Coll., vol. 72, Nos. 6 and 15; also the National Geographic Magazine for June, 1921, and March, 1922.

cular fireplace, 10 inches (25.4 cm.) deep, occupied a favored position near the center of the lodge; its diameter, as measured from the crown of its slightly raised rim, was 36 inches (91.4 cm.) but this was reduced to 22 inches (55.8 cm.) at its own floor level owing to the sharp slope of its adobe sides (pl. 1, fig. 2). The fireplace was filled

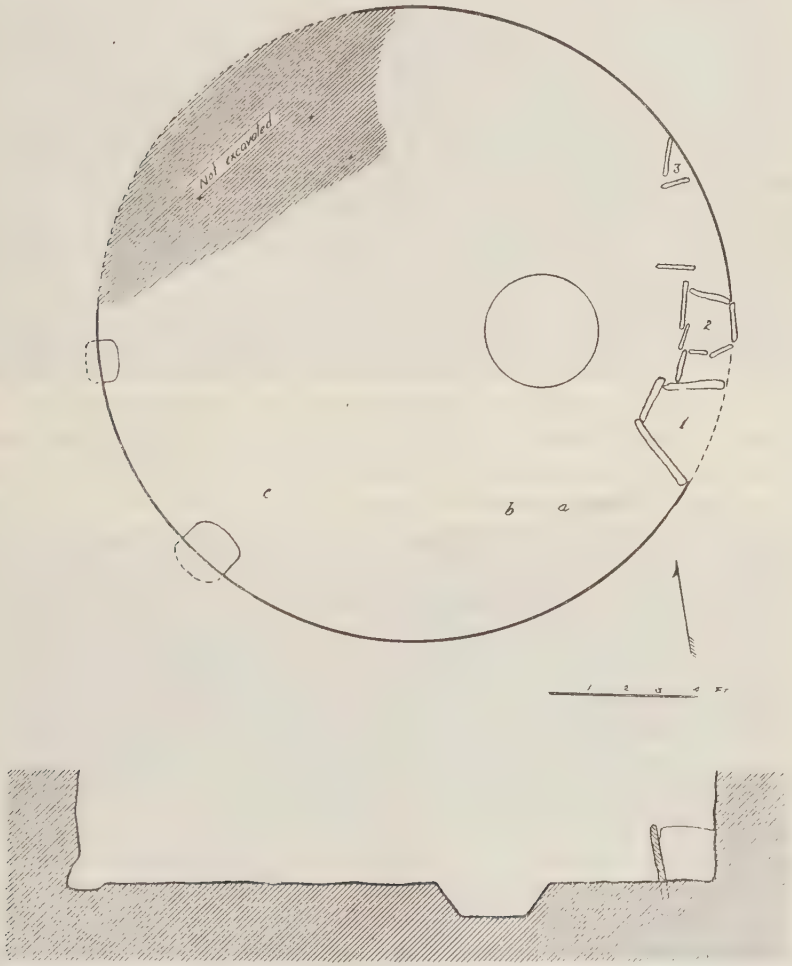


FIG. 1.—Pit House No. 1, ground plan and section, Chaco Canyon.

with coarse ashes in which bits of greasewood predominated. A mere handful of broken deer bones, split for the extraction of marrow, and a few small mammal and bird bones were scattered through the earth which filled the pit; none of these was found in the fireplace.

Against the east wall of the chamber were three bins each formed by upright slabs of sandstone (fig. 1; pl. 1, fig. 1). Two of these

bins were excavated by the expedition; in one were several fragments of an earthenware bowl and a number of small objects probably utilized in pottery making. The chief function of these bins was most likely the storage of corn and other foodstuffs. A discarded metate, worn through, formed one of the inclosing stones on the north side of bin 2.

On the floor of the room, between its south wall and the fireplace, lay three shallow metates[4] or stone mills for the preparation of corn meal. A single mano, the handstone invariably used in connection with each mill, had been placed under the edge of metates b and c, respectively (fig. 1). That the presence of these primitive grinding instruments is not unusual in ancient dwellings of this character is evident from explorations by Dr. Walter Hough near Luna, N. Mex., during which he observed that "every pit house revealed on excavation a mealing stone lying on the floor near the fireplace."[5]

Two receptacles for the protection of small objects had been carved into the adobe wall of the room in its southwestern quarter (fig. 1). The floor level of each lay somewhat below that of the room, a feature which has been noted, also, by Mr. Earl H. Morris[6] in pit houses between the San Juan River and the Continental Divide, 70 miles east of the La Plata. Although placed much lower in the wall, these repositories were probably identical in purpose with the small cubbyholes frequently found in dwellings of later periods.

Relatively few artifacts were recovered during excavation of this pit dwelling (the northwest quarter was not completely cleared) and these, unfortunately, do not afford a satisfactory index to the cultural attainments of their original owners. A grooved stone maul (315892),[7] two hammerstones (315893), and five bone awls (315894) may or may not belong to the pit-house culture. There is nothing distinctive about them since objects of this kind, made from raw materials near at hand, are very much alike in early Pueblo dwellings throughout the entire Southwest. The neck of an undecorated jar (315900) and several sherds from a similar vessel (315901), said by the Indians to have been found near the middle of the room and well toward the surface, are certainly not of pit-dweller origin. The high straight neck (2½ inches) of the former and the lack, in both specimens, of the broad bands so characteristic of pit-house cooking jars is sufficient to connect the fragments with the small-house refuse piles which lie near by and slightly above the pit dwelling. In the

[4] The three metates averaged 17 by 24 by 2 inches (43.1 by 60.9 by 5.08 cm.).

[5] Proc. U. S. Nat. Mus., vol. 55, p. 416.

[6] 33d An. Rep., Bur. Amer. Ethnol., p. 186.

[7] The catalogue numbers given for specimens not figured are those of the United States National Museum, to which the National Geographic Society has presented the collections from the dwellings here described.

1. SLAB INCLOSED BINS IN PIT HOUSE NO. 1. THE UNEVEN FLOOR, THE SLOPE OF SOUTH WALL, AND THE CRUDE SURFACING OF THE LATTER ARE ALL APPARENT IN THIS ILLUSTRATION.

2. PIT HOUSE NO. 1, PARTIALLY EXCAVATED. THIS VIEW, TAKEN FROM THE NORTH, SHOWS THE FIREPLACE IN THE MIDDLE FOREGROUND AND BEYOND IT THE THREE METATES AND ONE OF THE SUBWALL REPOSITORIES.

Photos by Neil M. Judd. Courtesy of the National Geographic Society.

1. SEARCHING AMONG THE BLOCKS OF FALLEN ADOBE BELOW PIT HOUSE NO. 2 FOR POTSHERDS AND OTHER ARTIFACTS. THE CROSS SECTION OF THE ROOM WILL BE NOTED IN THE SHADOW AT THE RIGHT ABOUT MIDWAY OF THE BANK.

2. IN THIS NEAR VIEW OF PIT HOUSE NO. 2, BEFORE EXCAVATION, THE WEST BRANCH WILL BE NOTED AT THE LEFT; THE DIVIDED FIREPLACE APPEARS JUST ABOVE THE INDIAN, AND THE POSTHOLE WHICH MAY HAVE HELD THE LADDER IS SEEN AT THE RIGHT. THE CHARRED REMAINS OF ROOFING TIMBERS WERE BOUND TOGETHER BY EXTREMELY HARD ADOBE AND SAND STRATA.

Photos by Neil M. Judd. Courtesy of the National Geographic Society.

course of uncounted centuries these intrusive sherds may well have shifted along with the blown sand and lodged on the flat area above the pit.

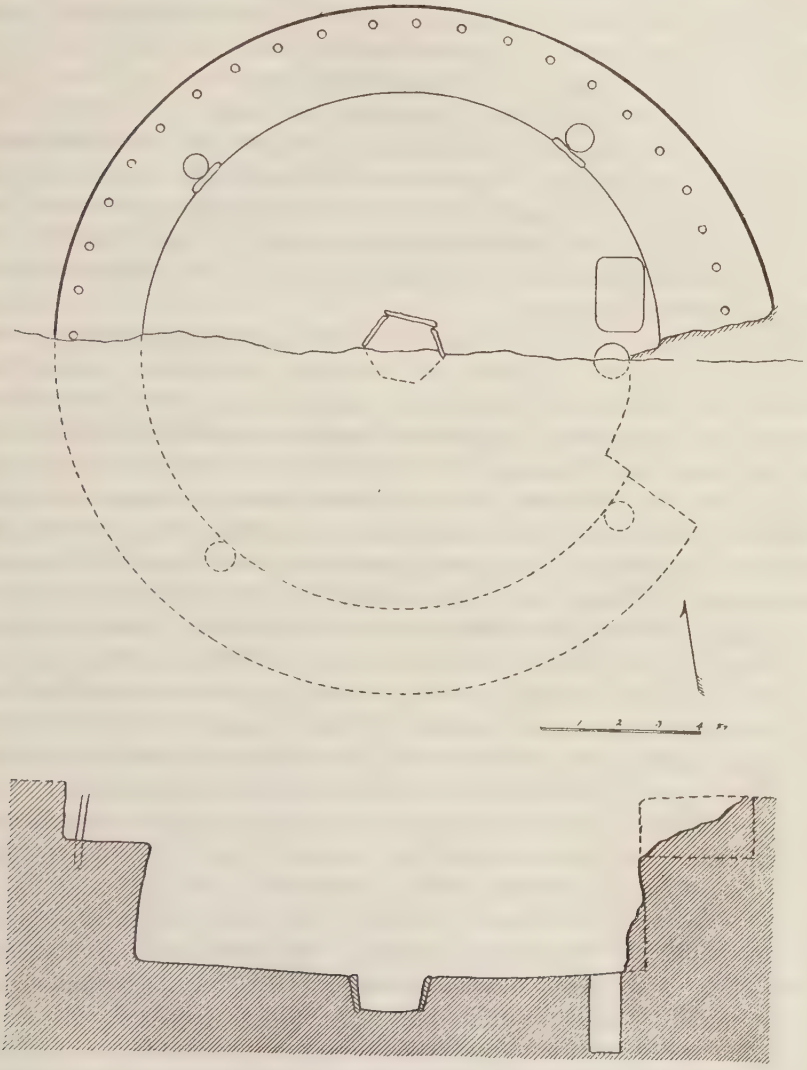


FIG. 2.—Pit House No. 2, Chaco Canyon.

PIT HOUSE NO. 2.

A second Chaco Canyon pit house (fig. 2; pl. 2, figs. 1 and 2; pl. 3, fig. 1) which, happily, affords a much clearer estimate than that just described of the degree of cultural advancement reached by its builders, was brought to the writer's attention by one of his Navajo friends early in the spring of 1922. This second ruin stands

about 1 mile (1.60 k.) east of Pueblo Bonito and was exposed by caving of the north arroyo bank during the heavy rains of the previous summer. Here the arroyo is fully 30 feet (9.14 m.) deep and the ancient dwelling was almost equally divided when the huge masses of adobe crashed from their resting place and rolled out 50 or 75 feet (15.2–22.8 m.) from the bank (pl. 2, fig. 1).

Some idea as to the geophysical changes which have taken place in Chaco Canyon since this prehistoric dwelling was inhabited may be gained from the fact that the rim of the fireplace (pl. 2, fig. 2, directly above the Indian) is 12 feet 2 inches (3.708 m.) below the present valley surface and that approximately 6 feet (1.82 m.) of silt had been deposited above the original roof level of the house following its abandonment.

The cross section (pl. 2, fig. 2) of this second pit house, when first seen by members of the Pueblo Bonito Expedition, revealed a tangled mass of burned and rotting roofing poles closely packed in blown sand and adobe. This débris largely occupied that portion of the pit lying below the level of a broad bench, plainly seen on the western side of the room; above the bench were successive layers of sediment, deposited both through wind and water action, which had gradually filled and, later, completely hidden this underground habitation. A bench corresponding to that on the west did not at first appear on the eastern side but a split posthole, 9 inches (22.8 cm.) in diameter by 22 inches (55.8 cm.) deep, quickly attracted one's attention. The floor of the room was slightly dished, its middle being 3 inches lower than its periphery. Although but half of it remained for examination, this subterranean dwelling appeared to offer so much of interest in connection with the general problem of human occupancy of Chaco Canyon in prehistoric times as to warrant its excavation, a not inconsiderable task owing to the depth and extreme hardness of the clay which filled and covered the pit.

Once the earth had been removed from that portion remaining in the bank this ancient pit dwelling was found to agree closely with those described by other explorers. Its form, its manner of roofing, and the culture of its builders could be pictured with satisfying accuracy. Although smaller than that excavated in 1920, this second pit house was likewise round, being 12 feet 9 inches (3.88 m.) in diameter. The middle of its slightly concave floor was occupied by a slab-lined fireplace 9 inches deep by 22 inches in diameter (22.8 by 55.8 cm.). A bench 35 inches (88.9 cm.) high and 26 inches (66 cm.) wide enlarged the room on its northern half, but on the east, only a few inches from the face of the bank, this bench is unexpectedly interrupted by a broken wall of undisturbed adobe which appears to have been not more than 16 inches (4.64 cm.) high.

At this point the banquette had been widened to 36 inches (91.4 cm.) and the height of the outstanding wall of clay probably affords a reasonably accurate idea as to the space between the top of the bench and the original valley surface. A second, though now shattered, block of adobe left by the original excavators connected the face of the bench with the posthole previously mentioned. It is, of course, quite impossible to establish the conditions which obtained here at the time of occupancy, that is, as to the width, or function, of these two protruding sections of unexcavated earth. Being toward the east, they may have formed or supported a series of steps connecting with an entrance through the roof, but the fact that so little remained after caving of the bank leaves this uncertain. One is inclined to the belief, rather, that the large post which stood just within the wall at this place was provided with notches and served as a ladder.

In roof construction this second Chaco Canyon pit house is not unlike others of the type found elsewhere. Two posts, 7 inches and 8½ inches (17.1 and 21.5 cm.) in diameter, stood about 2 inches (5.08 cm.) inside the face of the bench at the northwest and northeast quarters, respectively (fig. 2); since the room has been almost equally divided it may be assumed that corresponding posts also stood in that portion of the dwelling now missing. Vertical sections had been gouged from the adobe bench and, after the posts had been placed and blocked in with stone and earth, the front of each cut was closed with stone slabs and plastered over. Among the slabs covering the northwest upright was a metate, worn through at the bottom, set on end with its grinding surface toward the post. Several coats of smoked plaster had been applied to the slightly concave face of the bench, and its upper surface was hard and smooth as though from long usage.

Twenty-two small posts of about 2 inches diameter had been placed around the exposed banquette at an average distance of 20 inches (50.8 cm.) from its face. These were set approximately 14 inches apart and all stood in an upright position extending and inclining, no doubt, to cross pieces supported by the four principal posts already noted. The presence of the latter carries the inference that that portion of the roof between the posts was flat or nearly so. And it is not unreasonable to assume that the small uprights reaching above the bench originally supported layers of brush and grass, overlaid with loose earth taken from the excavation.

It is to be recalled that the bench in this pit house was approximately 16 inches below the valley surface at the time of construction and that the floor of the dwelling was 35 inches lower. These

combined measurements, however, probably fall considerably short of the actual ceiling height. Just why the ancient artisans deemed it desirable to build a wall of posts and brush above the bench in preference to utilizing the hard adobe face of their excavation is not clear but such practice seems to be characteristic of pit houses in which the bench is present. Kidder and Guernsey[8] describe a pit dwelling in the Monuments district of northeastern Arizona in which roofing poles, driven into a narrow bench at an angle, appeared to have met above the middle of the lodge. Dr. J. W. Fewkes[9] has observed a similar method of construction on the Mesa Verde National Park. Hough,[10] writing of pit villages near Luna, and Morris,[11] reporting on excavations between the San Juan River and the Continental Divide in Colorado, both noted the occurrence of large posts as roof supports but say little or nothing of an encircling bench and lesser timbers reaching from it to the main beams. Dwellings similar to, but seemingly more elaborate than, these circular structures in that the benches were faced with stone slabs and the upper walls were of wattle work, have been discovered in southwestern Utah caves by the present writer.[12]

Several slab-inclosed receptacles, corresponding with those in the other local pit dwelling (p. 401), formerly rested against the south wall of the room, the stone slabs and adobe flooring of such bins having been found among the huge blocks of earth caved from the bank. These bins are, of course, now completely shattered and but little of interest could be gathered from their broken remains. One of the number, a box 29 inches wide and 10 inches deep (73.9 by 25.4 cm.) had been paved with waterworn cobble stones; on its floor lay a quantity of charred vegetable matter among which were corncobs and kernels.[13] Other corncobs and one squash seed were found among the débris.

No traces of subwall depositories, such as those observed in our first pit house (p. 402), were noted in this second structure but a rectangular depression, 15 inches wide by 22 inches long by 3½ inches deep (38.1 by 55.8 by 8.88 cm.), had been scraped from the floor below the eastern end of the bench (fig. 2).

MINOR ANTIQUITIES.

The few artifacts of unquestioned pit-house origin taken from the excavations of 1920 were found by the writer on the bottom of bin No. 1 (fig. 1) and consist of a small mass of kaolin (315898), a

[8] Bull. 65, Bur. Amer. Ethnol., p. 44.
[9] Smithsonian Misc. Coll., vol. 72, no. 1, p. 58.
[10] Proc. U. S. Nat. Mus., vol. 55, p. 415.
[11] 33d An. Rep., Bur. Amer. Ethnol., p. 186.
[12] Smithsonian Misc. Coll., vol. 72, no. 1, p. 66, 1919.
[13] A bowl (324806) found beside the fireplace was partially filled with charred, shelled corn.

rubbed piece of red ocher (315895), an unworked bit of compact yellow clay, probably intended for paint, a small ball of impure sandstone (315897), and two disconnected portions of an earthenware bowl (315901). The latter only are of especial interest at this time.

Its fragments show the bowl to have been about 7 inches (17.01 cm.) in diameter and 3½ inches deep (8.88 cm.) with a thickness of less than three-sixteenths inch. The paste, which is rather coarse and filled with tiny quartz crystals, has been fired to a uniform pinkish yellow. Although its outer surface remains somewhat uneven, the interior exhibits a fine, smooth finish on which a geometric design has been drawn with dark red paint. This design can not be accurately reconstructed from the sherds at hand, but it consists, apparently, of a central decoration of thin, parallel lines with terraced or "cloud" elements, joined to a horizontal band just within the rim by four V-shaped units from which hang solid triangles and within which is a single row of dots inclosing an open triangle. These fragments differ both in paste and decoration from sherds associated with the more recent stone-walled ruins near the pit house and indicate that the inhabitants of the latter were not unskilled in the art of pottery manufacture.

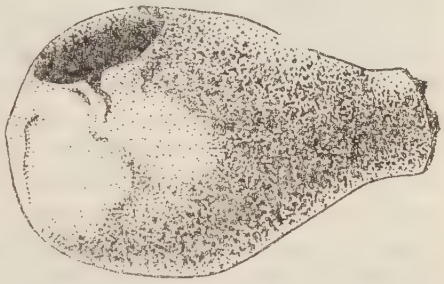


FIG. 3.—Earthenware pipe.

An earthenware pipe of rather unusual shape (fig. 3) was found on the floor of the room between the fireplace and the slab bins. Its bowl resembles a miniature jar with a constricted opening and with one side drawn out to form a round stem, now broken; its surface is roughly smoothed and bears no trace of ornamentation. The stem had been perforated by pushing a coarse straw from the bit toward the bowl while the clay was yet plastic. The specimen is 1¼ inches high by 1½ inches wide by 2¼ inches long (3.12 by 3.81 by 5.71 cm.) with a three-fourths inch orifice; no evidence of use is to be seen.

The really abundant material recovered at the site of the second pit house, excavated in 1922, happily balances the paucity of specimens from the first. Among the heavy blocks of clay which had crashed down into the arroyo (pl. 2, fig. 1) and in the silty deposits which filled that half of the ancient pit house not destroyed were numerous potherds and other artifacts abandoned by the one-time inhabitants. Several jars had been left in or adjacent to the slab bins

which formerly stood against the south wall; their impressions were plainly visible in some of the larger adobe masses and their scattered sherds were recovered in considerable quantities. Altogether, 11 earthenware jars and 8 bowls have been restored from the pottery fragments collected at this site (pl. 3, fig. 2).

Certainly the most noteworthy of these vessels are the two large black-on-white water jars shown in plate 4. One (a) stands 16½ inches (41.1 cm.) in height and has a diameter of 13½ inches (34.2 cm.); its orifice is oval in shape, 2¾ inches wide by 4 inches long (6.78 by 10.2 cm.). A crack running downward from each end of the opening indicates a slight unintentional misshaping, perhaps due to pressure early in the firing process. The second jar (b) is 17¾ inches (45 cm.) high by 14½ inches (36.8 cm.) in diameter; its mouth, also oval, is 2¾ inches wide by 4 inches long (6.98 by 10.1 cm.). In both vessels the body is decorated by an elaborate geometric pattern and, above this, interlocking spirals representing plumed serpents. Three seems to have been the favorite number for such spirals but in the second jar (b) there are five, the serpents being represented by single, somewhat angular lines, above which is an encircling, zigzag line. Fragments of four other large jars, not sufficiently complete to warrant restoration, show similar treatment but, on one of these, the body ornamentation reached nearly to the rim and on another, whose upper portion is entirely missing, interlocking plumed serpents form the basic feature of the main design. In all six specimens the exterior surface has been washed with a thin white slip as a background for the black paint of the design. None of these water jars was provided with handles or the outflaring rim so typical of later pre-Pueblo ollas.

One small jar (pl. 5, fig. 1) has this noticeable difference from the larger vessels: A constricted shoulder permits a more direct approach to the rim and provides the specimen with what might be called a neck. A reddish-brown body decoration has wholly disappeared except in one limited area; the upper portion shows three horizontal, wavy lines adjacent to the rim.

Three of the eight bowls recovered have interior decorations, drawn with black pigment over a white slip (pl. 6); the rim edge of each has been flattened by rubbing and carries a black line, a characteristic feature of bowls from the principal Chaco Canyon culture. One specimen (324805), rather cruder in workmanship and more straight-sided than the others, is ornamented with four horizontal bands crossed at intervals by two or four vertical lines. This

1. PIT HOUSE NO. 2 AFTER EXCAVATION, SHOWING THE EXPOSED BENCH AND DEPTH OF THE SILTY DEPOSITS ABOVE IT. THE STONE SLAB EMBEDDED IN THE FRONT OF THE BENCH, AT THE LEFT OF THE UPPER INDIAN, COVERS THE GROOVE IN WHICH ONE OF THE FOUR ROOF SUPPORTS HAD STOOD.

2. CHACO CANYON AS SEEN FROM THE SOUTHEAST CORNER OF PUEBLO BONITO. PIT HOUSE NO. 2 WAS FOUND NEAR THE ARROYO BANK INDISTINCTLY SEEN IN THE MIDDLE DISTANCE, ABOUT MIDWAY BETWEEN THE TWO HIGHEST PORTIONS OF THE NEARBY WALLS AND DIRECTLY ABOVE THE OLD DOOR.

Photos by Neil M. Judd. Courtesy of the National Geographic Society.

a

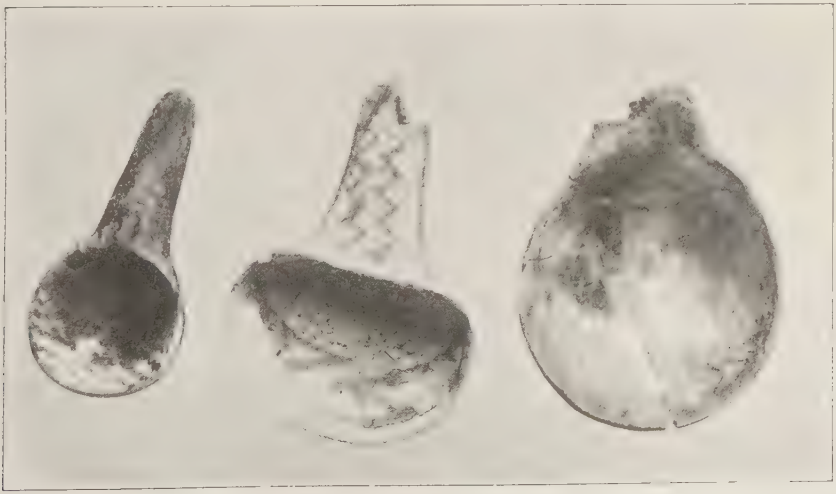
b

WATER JARS. FROM PIT HOUSE NO. 2.

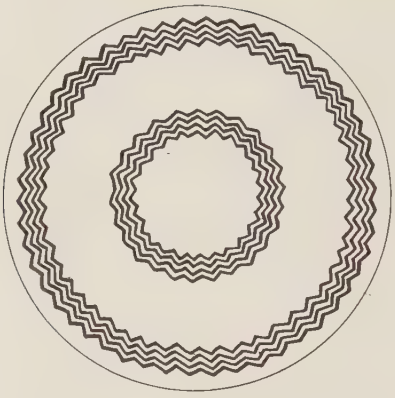
a b d

1. EARTHENWARE JARS AND COOKING POTS, PIT HOUSE NO. 2.

2. EARTHENWARE LADLES, PIT HOUSE NO. 2.



3. EARTHEN LADLES (INSIDE VIEW OF FIGURE ABOVE).

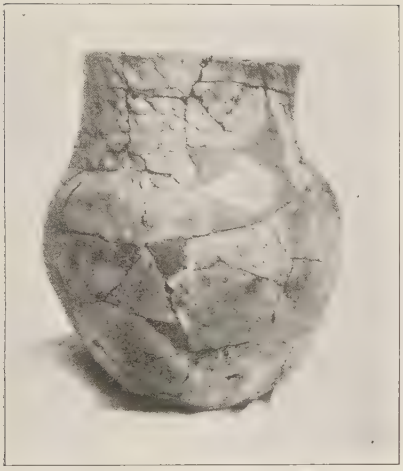


1

2

3

1, 2, 3. DECORATION OF INTERIOR OF BOWLS.



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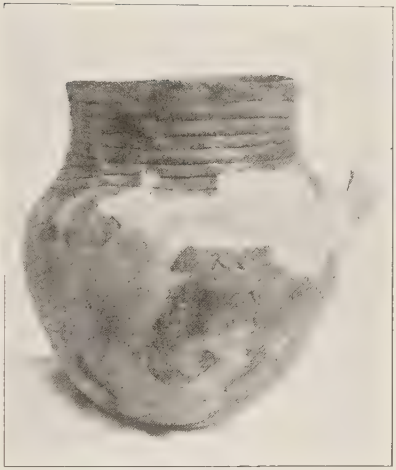

2

3

4

EARTHENWARE COOKING POTS. PIT HOUSE NO. 2.

design was painted with a reddish-brown pigment [14] upon a slate-colored wash; the evident lack of skill both in modeling and in decorating this particular bowl suggests the possibility of its being the work of a beginner. One of the bowls has a slightly incurving rim; in all the others the edge is reached directly, i. e., without apparent incurve or outcurve. The relatively thin rim in a majority of the vessels is rather carelessly rounded and noticeably uneven. In the specimens at hand, ornamentation was restricted to the polished interior of the bowls; the outside surface was not carefully smoothed and evidently did not receive the customary slip. Two bowls and a small cuplike vessel were not decorated in any manner; handles do not appear on any of the bowls in the collection.

In paste, in decoration, and in general workmanship these vessels from the Chaco Canyon pit house are characteristic of that phase of prehistoric culture in our southwestern United States commonly recognized as "pre-Pueblo." Fewkes, Kidder, Morris, and others have described the ware in their several reports of explorations throughout the San Juan drainage; almost identical specimens are figured by Hough in his important contribution on the Luna pit houses. Certain decorative elements on the pottery from this ancient Chaco Canyon structure, namely, the combination of thin, straight lines with areas of solid black, are suggestive of, but entirely distinct from, the designs on pottery from such great communal dwellings as Pueblo Bonito. The closely hachured designs so characteristic of the latter do not occur in pit houses so far as known.

Cooking pots, as represented in the collection (pl. 7), are typical of the pit-house culture as identified elsewhere. They present, indeed, one of its most distinguishing features. In shape they are globular with wide orifices; their rims are approached with little, if any, outflare. That portion of the jar between the shoulder and mouth is built up of broad bands of clay, one-fourth to three-fourths of an inch wide. These, however, are not true coils as in the case of the corrugated ware of the cliff dwellers and other prehistoric peoples; rather, each band has been added separately, overlapping that next below and the union of its ends carefully obliterated.

The paste from which these culinary vessels were shaped is coarser and more granular than that employed in manufacture of the bowls and decorated water jars previously described. It is noted, also, that although both inner and outer surfaces have been smoothed—the marks of tools are usually in evidence—no attempt

[14] Two brown bowls (324807, 324808), nicely smoothed on the inside, seem also to have been decorated with red paint, but this has so faded that the original color can not be ascertained with certainty; a small, light-colored cup (324809) has no ornamentation whatever.

has been made to improve the appearance of the vessel by application of a slip or surface wash.

Handles are present on five of the eight pots in this series. In one specimen (pl. 7, fig. 3) a single handle, consisting of three rolls of clay pressed together, was attached horizontally at the shoulder; in another instance (pl. 5, fig. 1) a handle of similar construction connects the shoulder with the edge of the orifice. Two vessels (pl. 7, fig. 2, and pl. 5, fig. 1a) are provided with flattened lugs, attached to opposite sides of the rim, whose under surfaces are gently curved to fit the finger. Dissimilar handles occur on the fifth specimen (pl. 5, fig. 1d), a thin, flat lug 1¼ inches long and five-eighths inch wide being attached vertically just below the rim on one side, while its opposite is a round lug with a slight downward curve. The latter handle, now largely missing, probably came to a blunt point about three-fourths of an inch from the side of the vessel. It should be noted that this is the only cooking pot in the collection whose outer surface is plain, the usual broad neckbands having been entirely effaced.

Three earthenware ladles (pl. 5, figs. 2 and 3),[15] restored from fragments gathered at this site, are so interesting as to merit brief description. In both form and ornamentation they are quite unlike. The smallest of the three has a round bowl and a handle which is slightly convex both above and below; the bowl of the largest is somewhat oval in appearance, due chiefly to its open or concave handle.[16] This second specimen is still further unique in that the near right-hand quarter of the bowl rim (as held in the hand) is one-half inch (1.27 cm.) lower than the remainder. The third ladle differs from the other two both in the shape of its bowl, which is considerably wider than it is long, and in the fact that its thick handle (flat on top and convex below) is attached to the bowl one-half inch below the rim of the latter. Perhaps as an additional decorative feature half of this upstanding portion of the rim has been cut away in a shallow curve, clearly shown in plate 5, figure 2. Each of these three ladles is decorated with black paint over a whitish slip applied to both inner and outer surfaces; in the second and third specimens a thin black line has been drawn around the rim edge.

Two additional earthenware objects from this second Chaco Canyon pit house should be mentioned. One of these (fig. 4) is a pipe made apparently from a portion of the handle of a gourd-shaped bottle.[17] Both ends have been rubbed smooth; the hole at the bit

[15] The only complete specimen is 5⅝ inches long by 2¾ inches wide (14.2 by 6.98 cm.)

[16] So far as the author is aware this type of ladle handle, so closely associated with the culture of Pueblo Bonito, has not previously been noted from pit houses.

[17] See Morris: 33d An. Rep., Bur. Amer. Ethnol., fig. 5, p. 197.

end has been gouged through with a flint drill. The larger opening shows unmistakably the use to which the object was put.

The second of these two specimens (324823) is a portion of what appears to have been the hollow handle of a ladle, reworked perhaps for intended use as a pipe. The smaller end has been carefully smoothed, while the fractured face of the opposite end shows but slight rubbing. A certain doubt arises in connection with this particular fragment, for its superior paste, its white slip, and its style of ornamentation all tend to place it with a culture later than that of the pit dwellers. There is no question, however, but that it was found in direct association with the other artifacts here described.

Several charred fragments of a small, finely woven coiled basket, gathered from among the débris in the arroyo, obviously add to the importance of this collection. The technique is "two rod and splint," as described by O. T. Mason.[18] Of still further interest are the charred remains of a pair of remarkably thin sandals found on the bench at the west side of the room. In these the weft is a twisted thread of a fine, unidentified fiber woven over parallel-warp cords of yucca which are arranged after the fashion of those in a cliff-dweller sandal figured by Kidder and Guernsey.[19] One may judge of the exceptional fineness of the weave in these specimens by the fact that there are no fewer than 9 warp and 32 weft strands to the inch. The importance of these fragments lies in the fact that, from the very nature of the dwellings, pit-house sandals and basketry are extremely rare. Discovery of these charred specimens, however, encourages the belief that other, perhaps more perfect, examples will be found as investigation of pit-house remains progresses.

FIG. 4.—Earthenware pipe.

In addition to the artifacts already mentioned, the collection includes two incomplete bone awls (324824), a reworked fragment of a shell bracelet (324825), two flint knives or scrapers (324826), and several stone hammers, manos, etc. Three broad, thin metates and a number of smoothing and grinding stones, recovered from the mass of fallen adobe (pl. 2, fig. 1), were not included in the material brought to Washington.

Lying upon the floor of the room between the fireplace and the west bench, its head to the northwest, was the incomplete skeleton of a young female. Caving of the arroyo bank had torn away all the

[18] An. Rep., U. S. Nat. Mus., 1902, p. 246.
[19] Bull. 65, Bur. Amer. Ethnol., fig. 38, p. 104.

leg bones; those of the trunk were mostly crushed by the weight of the roof poles and clay which had collected above them. All available fragments were preserved, however, for further study. The chief result of this subsequent examination [20] was the positive determination that the skull had been subjected to cradle-board pressure, resulting, in occipital flattening. Such artificial deformation, so characteristic of crania from cliff dwellings and other early Pueblo ruins, was scarcely to have been expected in a skull from a pit house in Chaco Canyon. From our meager knowledge of the pit dwellers (few adult skeletons have been found) we have rather assumed that they were a long-headed or dolichocephalic people, an assumption which has been drawn, perhaps, on too scanty information. As we become more intimately acquainted with the pit people through future exploration and as the character of their culture becomes more firmly established, it is not unlikely that these early conceptions will merit revision.

CONCLUSION.

On the basis of two incomplete dwellings only it would appear extremely unwise to attempt to draw any definite or final conclusion in respect to pit-house culture as found in the Chaco Canyon region. That other examples will be discovered seems almost certain; the unhappy fact in this connection, however, is that such vast changes have taken place in the canyon since arrival of these pioneer settlers as to preclude the possibility of identifying the sites of their subterranean homes through examination of the present valley surface. From preference the pit people seem to have constructed their shelters in open or exposed places, and these unprotected areas naturally have been subjected to the most intense leveling influence of the elements.

Perhaps the greatest contribution to American archeology which can be claimed for these two Chaco Canyon pit houses is the connecting link they afford between similar structures in localities so widely separated as Luna, N. Mex., the Mesa Verde National Park, Colo., and the Monuments district of northern Arizona. Their discovery increases the number of known pit dwellings and tends to draw them into one distinct group. Of scarcely less interest is the fact that finding an improvised pipe and basketry and textiles exhibiting extraordinary skill in weaving adds appreciably to previous knowledge of pit-house culture and strengthens its suspected close relationship with that of subsequent periods.

[20] The fragments have been examined by Dr. Aleš Hrdlička, Curator of Physical Anthropology, U. S. National Museum, whose report is incorporated in the above paragraph. It could not be learned, owing to its shattered condition, whether the skull was dolichocephalic or brachycephalic.

In his "Chronology of the San Juan area," Morris [21] assigns to the "pre-Pueblo" period dwellings both of the type herein considered and those of wattled construction in which upright slabs were occasionally incorporated in the basal portion of the wall. Such classification appears to be justified on the basis of ceramic remains only, and, indeed, the slight difference in architecture may prove to be merely a result of environment or the growth of a clan system, for "slab houses" are found in groups more frequently than are pit dwellings. But Morris observes that a majority of the crania from pre-Pueblo sites is dolichocephalic, although some skulls with occipital flattening, possibly brachycephalic, have been recovered. It remains to be seen, therefore, whether this peculiar custom of artificial deformation is identified with pit houses only or with both types of pre-Pueblo habitations equally; whether it is early evidence of the adoption of a rigid type of cradle board or the immigration of a separate people, as has commonly been held heretofore.

Surely one of the most pressing needs of southwestern archeology to-day is a clearer definition and a broader appreciation of the "pre-Pueblo" stage in our chronological system. It was the very germ of that widely distributed culture which found its greatest prehistoric development in such marvels of aboriginal creative genius as Pueblo Bonito and which still struggles to maintain its individuality in modern pueblos such as Walpi, Oraibi, Zuñi, and others. But these needs may be realized only through painstaking labor in crude, ill-defined ruins, often difficult of access and, be it said with regret, so unpromising that they are rarely left solely to the choice of the student of ancient history.

[21] Proc. Nat. Acad. Sci., vol. 7, no. 1, p. 20, 1921.

THE COLLECTIONS OF OLD WORLD ARCHEOLOGY IN THE UNITED STATES NATIONAL MUSEUM.

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[With 57 plates.]

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INTRODUCTION.

The collections embrace two great sections of the antiquities of the Old World, illustrating: (1) the culture of the so-called "historic" nations, especially those who were settled around the Mediterranean Basin (Egyptians, Babylonian-Assyrians, Syro-Palestinians, Greco-Romans), from which our own civilization is largely derived; (2) the diversified cultures of various peoples in Europe, Asia, Africa, and Australasia, imperfectly or not at all represented in contemporaneous written documents, and commonly designated as "prehistoric" archeology. Though the collections are by no means complete and well rounded out, since no systematic explorations and researches have been extended to foreign countries, still they contain a considerable, varied, and important series of specimens, both interesting and instructive to the public as well as the student. The following pages will first give a survey of the material contained in the collections, combining the chronological order of the phases or stages of the cultural remains with their geographic provenance; and then a sketch of the exhibit of a selection from this material.

PREHISTORIC ANTIQUITIES.

Remains of the Stone Age.

I. THE PALEOLITHIC PERIOD.

The Stone Age derives its name from the fact that during that age man manufactured his tools and weapons chiefly of stone. These implements constitute the earliest known cultural traces of the human

race. They are assigned to the Pleistocene, or Quaternary period of geology, which includes the so-called Ice Age. The two chief sources of these traces are the river gravels and the caves, rock shelters, and other inhabited sites. The flint implements occurring in the former are found to have the same color and surface characteristics as the unworked nodules among which they lie, and are often abraded in the same way, indicating original inclusion in the formation. The period is determined not only by their geological position, but by their association with the remains of extinct species of mammals, such as the mammoth, rhinoceros, and reindeer. In some cases these bones are found in such relative position as to prove that they were deposited with the flesh still adhering to them, and it is also clear that the animals were contemporary with the makers of the flint implements.

In the caves occupied by man, his implements have been left with the bones of animals on which he lived. Scattered upon the floor of the caves these objects have been sealed up by the infiltration of lime-charged water, and have remained undisturbed until our day. There can be, therefore, no doubt of their great antiquity.

The cultural conditions characterizing the Stone Age, however, were not common to the whole world during a certain definite period of remote antiquity. The beginning and duration of this so-called age varied in different regions of the earth, and with different peoples. It must, therefore, be held to denote a stage of human culture rather than a division of time.

The Stone Age is divided into: (1) a Paleolithic (older stone) period, and (2) a Neolithic (younger stone) period.

In the Paleolithic period six stages are generally distinguished, determined by the character of the relics found on certain stations in France, which are regarded as typical. They are, in chronological sequence, the Chellean, Acheulean, Mousterian, Aurignacian, Solutrean, and Magdalenian, names derived from Chelles (Seine-et-Marne), Saint-Acheul (Valley of the Somme), Cave of Moustier (Dordogne), Grotto of Aurignac (Haute-Garonne), Solutré (Saône-et-Loire), and la Madeleine (Dordogne). The names of these stations have been adopted by anthropologists as conventional landmarks for describing the progressive development of man, marking the divisions in his general march to the goal of civilized life. The characteristics of the culture of these six stages are briefly as follows:

1. *Chellean stage.*—The distinctive implement of the Chellean phase of culture, frequently its sole representative, is the hand ax (coup-de-poing, also called boucher, after its discoverer, Boucher de Perthes). It was produced by detaching flakes from a nodule, or pebble, bringing it to a point, while leaving a heavy base, sometimes

retaining the natural crust. The edges are more or less wavy, owing to alternate chipping on opposite faces. It varies from 2 to 10 inches in length, and was fitted for grasping in the hand without a haft. It might have been used for a number of purposes, as cutting, digging, scraping, etc., and also as a weapon.

The animals represented by the fossil remains imbedded in the Chellean river-drift deposits were the straight-tusked elephant (*Elephas antiquus*), the large hippopotamus, the woolly rhinoceros (*Rhinoceros tichorhinus*, or *merkii*), the Trogontherium, the cave bear, and the cave hyena, pointing to a warm, moist climate, perhaps one of the milder intervals of the Ice Age.

2. *Acheulean stage.*—The hand ax, or boucher, characteristic of the Chellean Age is also associated with this stage, but is distinguished by better workmanship and a more elegant form. It is flatter and thinner. The flaking is finer, and the edges are worked by secondary chipping into an even, regular line, rendering the implement more trenchant and efficient. The natural crust of the stone, if not altogether removed, is only visible in small patches. In the upper Acheulean stage the hand ax assumes a fine lanceolate form, and is accompanied by a great variety of smaller implements.

In addition to the animals of the preceding Chellean stage, the mammoth (*Elephas primigenius*) was an inhabitant of western Europe during this period.

3. *The Mousterian stage.*—The most characteristic implement of this stage is a flake struck off from a nodule, chipped on one side giving a curved cutting edge, opposite which is usually left a portion of the original crust of the stone to serve as a grip. The nodule held in the hand was carefully chipped on one surface, giving the desired form, and then with a well-directed blow the entire worked surface was severed from the rest of the nodule. The tool thus produced presented a sharper cutting edge, and required less labor in its manufacture than the hand ax. Along with it were scrapers, lance heads, etc.

It is believed that about this time the climate became colder and man first made his home in caves. Animals adapted to a cold climate, as the mammoth, rhinoceros, reindeer, arctic fox, etc., became abundant, while the hippopotamus and other creatures usually associated with warm climates, gradually disappeared from Europe.

The formations of this stage furnish earliest known osseous remains of man (found in Neanderthal and Heidelberg, Germany; Krapina, Croatia; Spy, Belgium; Le Moustier and La Chappelle-aux-Saints, France; and Ipswich, England).

4. *Aurignacian stage.*—The stone industry of this stage is characterized by slender, pointed flakes, carefully retouched all along

the cutting edge and marked by regularity and fineness of the secondary flaking.

More important is the introduction of a new material, namely, bone, which while tougher and less brittle than flint is capable of taking a fine point. Bone points with cleft base, perhaps the predecessors of the needle, are characteristic of this stage. Other typical tools are awls carved out of the metacarpal of the horse or reindeer with the knuckle end left to form a handle; they are chiseled with transverse incised lines.

This stage also marks the birth of the fine arts: Sculpture, painting, and drawing made their appearance.

The presence of the reindeer in this and the succeeding stages gave them together the designation of the reindeer epoch.

5. *Solutrean stage.*—During this stage flint working attained a high degree of excellence, to be surpassed, however, in the Neolithic period. The most characteristic forms are leaf-shaped blades, which may have been used, according to size, as arrowheads, lance heads, or even as knives, and shouldered points having one side of the hilt cut away, leaving a tanglike projection. It is probable that the chipping of flints which hitherto had been effected by percussion with a stone hammer, was now also performed by pressure by means of bone fabricators, which permitted of more refined finish. Bone and ivory continued in use, and the earliest bone needles are met with in the upper horizons of this stage.

The horse was abundant, but the reindeer, the mammoth, the urus (*Bos primigenius*), etc., also were represented. Along with the remains of implements and animal bones a number of hearths have been found.

6. *Magdalenian stage.*—In this stage prominence was given to the manufacture of all sorts of objects of bone, ivory, and horn, with a corresponding decline in the flint industry. The flint implements are less elaborate and often lacking in finish; they consist to a great extent of long, thin flakes and splinters which have been converted by a minimum of dressing into scrapers, knives, gravers, drills, and other simple tools. The occurrence of bone harpoons may indicate that the people of this time were fishermen as well as hunters. Aside from sculpture and line engraving some of the paintings on the walls of caves are credited to this period.

The fauna is represented by animals of a cold climate: The reindeer, stag (*Cervus elaphus*), Irish deer (*Cervus megaceros*), bison, artic hare, etc. The mammoth had disappeared.

These stages may be separated into two groups. The older, represented by the two first stages, is practically confined to the diluvial, or river-drift deposits; the typical implement is the crudely chipped almond-shaped hand ax. The younger group, comprising

the four later stages, is characterized by a greater variety of implements which are also noteworthy, both for their greater artistic finish and their wider range of usefulness; they are found principally in the caverns and rock shelters. It is also marked by the appearance of bone implements and the beginnings of the arts of sculpture and painting.

"*Eoliths.*"—Preceding the Paleolithic period is assumed by some archeologists an "Eolithic period" ("dawning stone age"), which is supposed to have reached back into the Tertiary epoch of geology. The finds attributed to the "Eolithic" period are roughly worked pebbles, or nodules, slightly trimmed on one margin, deeply stained to a deep, ocherous brown color, indicating age, and usually bearing marks of drift action. They have been found in the south of England, notably on the chalk plateau of Kent, and in some districts of France, Belgium, and Spain. They are believed to represent the earliest known attempts of man at tool making.

Although it would seem to be a necessity that man should have passed through an earlier stage before arriving at the precision of workmanship and the fixed types characteristic of the Paleolithic period, the geological age of these relics is not well determined and it is even a question in many cases whether they are the work of human hands, as flints may be chipped by pressure of shifting gravel, glacial action, or falling masses. It is therefore doubted by some archeologists whether the crude flints assigned to that period are artifacts or are of natural origin.

Azilian-Tardenoisian period.—As connecting links between the Paleolithic and Neolithic periods are regarded the relics found in the cavern of Mas d'Azil (provincial form of Maison d'Azyle), Ariège, and in Fêre-en-Tardenois, Aisne. The typical implement of the former locality is the flat harpoon of red-deer horn, while the finds in the latter place are characterized by small flint instruments and tools, affecting geometrical forms, such as triangle, trapeze, rhomboid, etc.

II. THE NEOLITHIC PERIOD.

In the Neolithic period the physical conditions were similar to those of modern times. The configuration of the land was practically the same as at present and the severe arctic conditions had passed. Of the animals which lived with the cave man, some, like the mammoth, had become extinct, others, including the reindeer, had wandered to distant regions. The animals associated with man belonged to existing species.

The implements and weapons of Neolithic times were made in a great variety of well-defined forms and exhibit a high grade of

workmanship, and by providing them with hafts or handles they were made more efficient, while the adoption of polishing or grinding made it possible to employ other hard stones, such as diorite, serpentine, and basalt, not so tractable for chipping as flint. Polished stones, however, are not the main characteristic of the Neolithic period. For not only were a large class of the more delicate implements and weapons, such as knives, scrapers, spearheads, and arrowheads rarely ground or polished, but even axes of exceptionally fine workmanship were sometimes shaped by chipping alone. More important were the great strides which Neolithic man made in the direction of what is summed up under the name of civilization. He no longer lived, like his predecessor of Paleolithic time, exclusively by the chase, but tilled the ground, cultivating cereals for food and textile plants for raiment. He tamed animals and trained them to domestic use, developed the art of making pottery, and for shelter he often constructed wooden dwellings, raised on piles, in lakes and rivers. From the elaborate chambered graves (Barrows) erected over the bodies of chiefs, as well as from other megalithic monuments (Menhirs, Cromlechs, Dolmens) which still exist, we may, perhaps, safely infer the birth of religious sentiments and beliefs during, if not before, that time.

According to the degree of civilization attained, as illustrated by the remains discovered, there are distinguished three divisions in the Neolithic period:

1. *Early Neolithic*, called the Campigny period, from one of its typical stations (Seine-Inferieure, France), characterized by rough, indeterminate flint implements, the tranchet hatchet of the Danish kitchen-middens, axes sometimes slightly polished. Dog domesticated. The habitations consisted of caverns and rock-shelters, and hearths hollowed out of the earth. No burials yet found have associated relics of art.

2. *Mid Neolithic* (Chassey, Saône-et-Loire, France, and Robenhausen, Switzerland).—Increased number of implements—daggers, saws, gouges, maces; deer-horn hafting of celts; polished stones; bows and arrows and lances. Building and navigation; nets, fishhooks. Baskets; spinning and weaving; cultivation of trees and crops. Domestication of animals. Manufacture of pottery with handles and ornaments. Alongside of caves and grottoes, pit and lake dwellings. Inhumation in caverns and grottoes, or in the earth, with objects deposited in the graves.

3. *Late Neolithic* (Carnac, Morbihan, France).—Artistic forms of celts; polished and perforated ax and hammer heads; jet, quartz, and steatite ornaments; engraving and sculpture; superior pottery

and general improvement on earlier industrial products; surgery, trepanning.

Improved habitations as demonstrated by the lake-dwellings of Switzerland and the Terremare settlements of Italy. Megaliths: Menhirs, stone circles, etc. Inhumation in dolmens, chambered barrows, and cists, with votive axes, amulets, and food.

The term Neolithic period does not imply a culture uniform in all parts of the world. In some regions the new arts developed sooner than in others. The progress in various regions and among different peoples toward civilization has always been very uneven. The culture of most, if not all, of the primitive peoples of historic times falls within the Neolithic stage.

The transition from the Stone Age through the Bronze Age to the Iron Age, and thus to what has been termed the "Middle level of civilization and onwards," is formed by the cultures of the lake dwellings and the Terremare settlements.

The Lake Dwellings.

The term is applied to habitations of wattle and daub raised, for greater security, upon piles within the margin of lakes or creeks at some distance from the shore. The existence of such dwellings was first noticed during the exceptionally dry season of 1853, when piles were exposed on the shores of the Lake of Zürich, in Switzerland, and soon numerous antiquities were brought to light. Since then it has been found that nearly all the lakes of Switzerland and many in the adjoining countries were peopled by lake-dwelling communities, living in villages constructed on platforms supported by piles at varying distances from the shores. Fifty such settlements have been enumerated in Lake Neuchatel, 32 in Constance, 20 in Bienne, and 24 in Geneva. Some of the settlements occupied an area 1,200 by 150 feet. The settlement of Pfäffikon covered 3 acres and is estimated to have contained 100,000 piles. A settlement in Lake Bienne extended over 6 acres and was connected with the shore by a gangway nearly 100 yards long by 40 feet wide. Often the settlements were accessible only by canoes. The huts raised upon the platforms were quadrilateral, measuring from 20 by 12 feet to about 27 by 22 feet. The walls were constructed of wattle coated with clay; the roofs were thatched with bark, straw, reed, or rushes; the floors were formed of clay well trodden down; the hearths consisted of stone slabs. The antiquities found on the various sites show that this manner of life continued from Neolithic times through the whole of the Bronze period into the earlier Iron Age.

The remains discovered on the sites of the Swiss lake dwellings, of which the settlement of Robenhausen on the moor which was formerly the bed of Lake Pfäffikon is considered the typical example, discloses an advanced condition of culture. The most important implement or weapon was the polished celt axe, which was usually of small size and made of hard stone, like diorite, serpentine, syenite, etc. It was often fixed in sockets of deerhorn or staghorn and set into a wooden handle, the elasticity of the horn socket rendering the handle less liable to split. Other weapons and implements were flint arrowheads and spearheads, saws and knives mounted in wooden handles with asphalt, stone hammers, and grain crushers. Along with a great variety of bone tools, wood was extensively employed for shafts, maces, bows, floats for nets, plates, ladles and spoons, tubs, canoes, etc. The art of the potter had considerably progressed, although the use of the wheel was still unknown. The vessels were often of large size, and sometimes roughly decorated with knobs and finger or cord impressions. The lake dwellers were no longer wholly dependent upon hunting for their livelihood. They cultivated wheat, barley, and millet, from which they made a rough kind of bread; they preserved apples and pears, and were also acquainted with raspberry and blackberry. The pieces of woven stuffs which have been preserved show that besides garments of skins, flax was grown and clothing woven from it. About 170 plants and 70 species of animals have been discovered and determined. Of the latter, 10 are fish, 4 reptiles, 26 birds, and 30 mammals. The animals which were domesticated were the ox, horse, dog, swine, sheep, and goat. Of the wild animals then inhabiting the district, the urus, bison, elk, and stag were among the most common.

The Terremare Settlements.

Remains of ancient settlements have been uncovered in mounds scattered over the plains of northern Italy which are traversed by the Po River and its tributaries, comprising the Provinces of Parma, Reggio, and Modena. Similar remains are also found in the valley of the Theiss, in Hungary. The name Terremare is derived from the marly soil of which the mounds are composed, known among the peasants of Italy as *marna*, or *merne*, by archeologists generally called *terra mara*, or *terre mare*.

The remains brought to light in these mounds represent pile-dwelling villages erected on land. The typical settlement was trapezoidal in plan, with its parallel sides running north and south, and two roads at right angles dividing it into four quarters. It was protected by a rampart and a wide moat and strengthened on the inside by buttresses. Outside were one or two cemeteries. The

average settlement covered about 7 acres. Over 100 stations have been discovered in Italy.

The stage of culture represented by the relics imbedded in the mounds is mainly of the early Bronze Age, but stretches back into the later Stone Age. Stone objects are few in number. Bronze was the chief material, represented by axes, daggers, swords, knives, razors, needles, pins, brooches, etc. Some stone and clay molds and pieces of bronze slag show that the technique of bronze casting was known. The practice of weaving is proved by a great variety and abundance of spindle whorls and loom weights. Wood was used in the manufacture of a great variety of objects, as handles, dishes, spoons, flooring, etc. Ornamental buttons, pins, combs, etc., were made of horn and bone. The ceramic art was extensively practiced. The decoration of pottery consisted of parallel and wavy ridges, incised triangles and crosses, knobs, circular impressions, etc. Small clay figurines, chiefly of animals, are the earliest specimens of plastic art found in Italy.

The inhabitants, though still hunters, derived their principal sustenance from agricultural and pastoral pursuits. They cultivated wheat, beans, vine, and flax, and had as domesticated animals the dog, pig, chickens, etc.

It is generally assumed that the Terremare folks were descendants of the lake dwellers who invaded the north of Italy in two waves from Central Europe, one toward the close of the Stone Age and the other after the Bronze Age had begun, bringing with them modes of house building which led to the erecting of pile dwellings on dry land. With the entrance of the Iron Age the Terremare settlements seem to have fallen into desuetude.

Remains of the Stone Age from Europe.

GREAT BRITAIN AND IRELAND.

The old Stone Age of England is represented by "eoliths," Chellean and Acheulean celts and picks, and a large variety of flake tools. They are derived from various localities, as the gravel of the Thames, chalk plateau of Kent, Thetford, the caves of Igtham, Robin Hood, Creswell Crags, Grimes Graves, Island of Jersey, etc. Of Neolithic material there are chipped celts, adzes, chisels, hammerstones, various scrapers, discoidal, triangular, and crescent shaped, and other flake tools, as knives, gravers, needles; a few shells and arrowheads, mostly coming from Beachamwell, Swaffham, Norfolk, and Ploughed Lands, South Downs, Sussex.

The osseous material (partly casts) consists of bones and teeth of the mammoth, hippopotamus, bison, rhinoceros, grizzly bear, cave hyena, reindeer, and fox.

Ireland furnished a considerable number of rude, nondescript quartzite implements, pounders or crushing stones, mauls, sling stones, hoes, and rudely worked flakes, but also polished celts and chisels, whetstones, drilled hammerstones, perforated stone rings, and a variety of arrowheads;[1] also a few fragments of pottery and bones and teeth of deer and ox. The material is derived from the caves of Ballymenoch and Craigavad and the counties of Antrim and Limerick.

From Scotland there are only an anvil of sandstone and a few flint flakes and cores, while Wales is represented by only a cast of a drilled hammer, carved with a netting design.

As a continuation of the Stone Age works into modern times in England may be considered:

THE BRANDON FLINT INDUSTRY.

Near Brandon, a village in Suffolk, England, there are prehistoric flint quarries which are being worked at present for the production of gunflint and strike-a-lights. The flint for this industry is obtained from Lingheath Common, about a mile southeast of the village; but the original quarry, believed to date from Neolithic times, was some years ago discovered in "Grimes Graves," a collection of pits 3 miles north of Brandon, where, at a depth of 39 feet, the "stone floor" was reached from which gunflints are manufactured at the present day.

The flints best adapted for the purpose of manufacture are those from the chalk formations. They are usually procured by sinking small shafts into the ground until a band of flint of the right quality is reached, along which low, horizontal galleries or "burrows" are worked. The tools used in quarrying are a one-sided, steel-tipped iron pick and a short crowbar. The lamp is made up of a candle stuck in a hollowed-out lump of chalk. The finished article passes through three processes of manufacture:

1. *Quartering.*—Sitting upon a stool which is slightly sloping forward a block of flint is placed on a leather pad on the workman's knees and broken up into splinters of about 6 or 7 inches square. The technique of quartering lies in breaking the stone so as to have a more or less squared-off edge to begin flaking from. Two sizes of hammers are used weighing 3 and 6 pounds, respectively. They are hexagonal in section and taper toward the faces.

2. *Flaking.*—This is the most difficult part of the process. The stone must be struck at a proper angle, with a certain force, and

[1] The bow and arrow became the ordinary weapon during the Neolithic period. The arrowheads preserved from that period present a variety of forms, as triangles, leaf and lozenge shaped, barbed, and with or without a stem. Polished arrowheads are found only in Ireland and Portugal.

by a particular portion of the face. The flaking hammer is made of steel, weighs about a pound, is square in section, and tapers toward the two ends.

3. *Knapping.*—Before the "knapper" is a wooden block into which an iron stake or chisel is let in and padded at the sides with leather to insure a rebound from the hammer stroke. The flake is taken in the left hand and held on the stake and with a chisellike hammer is cut into the required sizes and trimmed.

Eight different sizes of gunflints are made, their names and dimensions being as follows: Long Dane (for the lengthy Arab gun), $1\frac{3}{4}$ inches by 1 inch; fowling, $1\frac{3}{8}$ inches square; musket, $1\frac{3}{8}$ by $1\frac{1}{4}$ inches; carbine, $1\frac{1}{4}$ inches by 1 inch; horse pistol, 1 inch square; single (for single-barreled gun) and rifle, seven-eighths of an inch square; and pocket pistol, five-eighths by one-half of an inch.

Gunflints are still used by the tribes of central and western Africa, the Congo and Gold Coast, and the Arabs around the Mediterranean, all of whom are precluded—so far as it lies within the power of European Governments to enforce the prohibition—from acquiring modern firearms, such as breech-loading rifles and sporting guns. Factories exist at Birmingham and elsewhere which turn out nothing but flintlock and small arms, and Brandon provides the flints, the average output being 150,000 a week.

Tinder-box flints (strike-a-lights) are likewise still made for export. The Italian and Spanish peasantry prefer the tinder-box to any other means of obtaining light. It is also used in the humid African forests where matches prove unreliable. During the South African War 14,000 tinder boxes, provided with the best Brandon strike-a-lights, were issued to the British troops.

By a comparison of scrapers of prehistoric times with old strike-a-lights, of these with modern ones and with old English gunflints, an almost unbroken succession from the Neolithic period may be traced for the Brandon industry. Also the tools have not much altered since Neolithic times, if the ground and perforated Neolithic hammers are compared, save that iron or steel has superseded stone in the hammers and horn in the picks, and it may be mentioned that during the exploration of "Grimes Graves" there was found in the covered passage of a sand mound which had apparently been used for flint working in Neolithic times a pickax formed of flint fastened in a stag's antler.

FRANCE.

From France, the classic reservoir of the remains of the Stone Age, there is a considerable collection representing the several stages of the Stone Age period and various stations, caves, and

rock shelters where they have been located, as Chelles, St. Acheul, Le Moustier, La Madeleine, Les Eyzies, La Quina, Laugerie Haute and Basse, Bruniquel, Grotto de Bize, etc.

Of the Paleolithic period there are rude quartzite celts, Chellean and finely flaked Acheulean flint celts, Mousterian points and scrapers, especially of the Levallois type, Aurignacian, Solutrean and Magdalenian flake tools, as scrapers, points, gravers, borers, etc., mortars, breccia, pieces of stalactite and stalagmite, ochre and mullers for rubbing the ochre for painting, fossil shells. Besides, bone and horn implements,[2] as points and needles, spear throwers, harpoons,[3] and the so-called batons de commandment.

A small collection of plaster casts illustrates the art of the Paleolithic period. The esthetic arts of prehistoric times had their beginnings in the Aurignacian stage and reached their zenith in the Magdalenian stage, the final stage of Paleolithic culture. During these later stages of the Paleolithic period the cave dwellers cultivated both the graphic and plastic arts so assiduously and effectively that they have bequeathed an art gallery of some four or five hundred of engravings, sculptures, and even polychrome paintings, executed with such life and realistic naturalism as to excite astonishment and admiration.

The paintings were chiefly executed on the walls and ceilings of the caves. The materials for sculpture and engraving were the bones, horns, and tusks of the animals killed in the chase; the tools, sharply worked points or gravers of flint. The objects represented were chiefly the animals of the period and locality; representations of the human form are comparatively rare, and for the most part of inferior execution.

In the Neolithic period the industrial arts rather than the esthetic arts were cultivated. The latter were almost entirely confined to the decoration of pottery, the designs being mostly geometric in character and incised or impressed. The collection in the Museum comprises carvings and engravings.

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[2] Implements of horn and bone were common in the later stages of the Paleolithic period and continued to be employed through the Neolithic period. Bone was worked into chisels, awls, needles, arrowheads and spearheads, harpoons, whistles, and various other objects. The horns of the stag were made into celt sockets. Stout pieces of this material, perforated for inserting wooden handles, served as hammers and hatchets or hoes; and the antler was sometimes converted into a club by the removal of the prongs, except that near the base.

[3] The earliest harpoons occur in the Magdalenian stations, showing that at this stage of culture man added fishing to hunting as a means of sustenance. The larger specimens are invariably made of deerhorn, but the smaller ones are sometimes made of bone. Some harpoons are barbed on both sides, others on one only. At the base there are sometimes projecting knobs for retaining the loop of the cord by which the head was connected with the shaft. In northern Europe (Denmark) are also found harpoons of stagborn set with sharp pieces of flint as barbs.

Of the Neolithic period there are chipped and polished celts and chisels from various localities, the large cores (*livres de beure* from a supposed resemblance to pounds of butter) and flakes from the workshops of Grand-Pressigny (Indre-et-Loire)[4] knives, hammerstones, sling stones, grind,[5] mealing, and rubbing stones, worked horn, pottery fragments from dolmens, a plaster model of a dolmen,[6] clay beads and spindle whorls.[7] The osseous remains consist of the bones and teeth of the cave bear, rhinoceros, aurox, wild goat, reindeer, and horse, and fragments of a human jaw.

ITALY.

The prehistoric remains from Italy come largely from the Terramare stations near Modena, Castelaccio, and Castione, and from the lake dwelling stations at Lonato and Peschiera on Lake Garda, besides from the caves of Breonio and Lazarro, the island of Levengo, Sicily, island of Elba, Tuscany, and other localities. They include a variety of flake implements—scrapers, knives, points, arrowheads, some small chipped celts or chisels, and a number of finely polished celts and chisels. Mention is also deserved by a collection of *forma curiosa*, falsificates which originated in Breonio and in the neighborhood of Santa Anna, Verona. They consist of gray or brown flint, chipped in form of crosses, stars, squares, etc., representing neither tools nor weapons nor ornaments. There is also a considerable

[4] They are débris of a Neolithic workshop in the neighborhood of Grand-Pressigny, Department of Indre-et-Loire, France. The products of this industry, easily recognizable by their yellow waxen color, have been traced not only in various parts of France, but also in Belgium and Switzerland, so that apparently an export trade was carried on by the neolithic manufacturers.

[5] The grindstones used in shaping stone implements are generally of compact sandstone or quartzite and usually of two forms—flat slabs, often worn by use, and polygonal forms with several facets, convex and concave. In the operation of grinding, the grindstone was fixed and the implements were rubbed lengthways on the grinding bed, as shown by the longitudinal furrows, or striae, which characterize the implements; and from the coarseness of these furrows on many of the implements, especially the large ones, it would appear that some coarse and hard grit must have been used to assist the action of the grindstone.

[6] Stone monuments of huge size have been found in various regions the world over, and may be traced to the remotest times. Modern statues, obelisks, and other monumental works are the lineal descendants of these crude, unhewn monoliths. Such stones when standing single and isolated are called *menhirs;* when several of them are arranged in a circle or ring they are called *cromlechs;* while the term *dolmen* (table stone) is used for structures consisting of a large capstone supported on upright stones, usually three in number so as to form a chamber (see model in case). This chamber is sometimes embedded in a mound of earth or stones so as to present the form of a tumulus or cairn. It is believed that the primary object of these monuments was sepulchral, and that the implements, ornaments, etc., found in their neighborhood were votive offerings to the dead. The megaliths found in abundance in France, especially in the Province of Brittany, are regarded as marking the close of the Neolithic period.

[7] In their simplest form spindle whorls are disks of stone, clay, bone, or wood, from 1 to 1½ inches in diameter, pierced in the center for inserting the shaft. Sometimes they are conical and ornamental with incised lines. They served as flywheels to add momentum to rotary motion of the implement.

amount of pottery fragments and spindlewhorls. Osseous material is represented by the bones and teeth of the cave bear, cow and ox, besides the antler of a deer and horns of a bullock.

BELGIUM.

There is first to be mentioned a collection (partly casts) of Mesvinian and Strepyan artifacts. They are so called after the typical sites of their occurrence—Mesvin and Strepy, in Belgium. They consist largely of nodules and flakes of flint or brown chert, roughly chipped at the margin, and adapted to the purposes of hammering, cutting, abrading, and perforating. Dr. A. Rutot, of the Royal Museum of Natural History, at Brussels, Belgium, divides them, according to the degree of deliberate design which they exhibit, into three classes: Mesvinian, pre-Strepyan, and Strepyan, and considers them as representing transition stages from the Eolithic to the Paleolithic stages of culture.

The bulk of the implements from Belgium are of the Neolithic period and come from Spiennes (the flint mines of which belong to the best known, and where the flint was not only mined but manufactured on the spot and widely distributed from this center), Saint Symphorien, and the caves of Goyet, Sureau, Magarite, Montangle, Chaleux and Nutons. The collection includes miners' picks, cores, rudely chipped celts and chisels, hammers, and a variety of flake tools. Of bone implements there are casts of darts, points, daggers, harpoons and polishers, and celts and chisels made of deerhorn. Besides single animal bones, as the humerus, radius, calcaneum, etc., of the reindeer and ibex, there is a set of well-executed casts of the skulls and lower jaws of the brown bear (*Ursus arctus*), grizzly bear, the cave bear, the cave hyena, the elk, wolf, glutton, chamois, and goat.

SWITZERLAND.

Switzerland is represented by a considerable and varied collection of material coming in the main from the several settlements of the lake dwellers (see above the description of the lake dwellings, page 422) and from the cave of Kesslerloch (so-called because it has been a frequent place of resort of traveling tinkers), near Thayingen on Lake Constance. The collection comprises a wooden model of a lake-dwelling settlement and a variety of stone implements, chipped and polished. Among the latter may be mentioned finely worked

perforated hammers and celts,[8] and numerous chisel-like blades of nephrite and jadeite mounted in sockets of deerhorn, besides grinding and mill stones. The clay material includes a large collection of well-preserved pottery, some of large dimensions, spindle whorls, large clay rings, which were probably used as stands for vessels with rounded bottoms. Then an assortment of agricultural products, as various grains and fruits, threads and pieces of cloth and fishing nets, all in good preservation from having been carbonized. In the osseous material are represented the ox, pig, goat, deer, hare, etc.

YUGOSLAVIA (CROATIA).

There are from this region only a few casts of stone implements which were found with the remains of the Krapina man.

GREECE.

The small collection of obsidian cores and flakes came chiefly from Crete.

GERMANY.

The German prehistoric collection comes in the main from the islands on the Baltic Sea, with small contributions from the cavern of Taubach, near Weimar, and from Thuringia. It includes various flake tools, including Mousterian points and lunate knives, polished and perforated celts and ax hammers, chisels and gouges, daggers and spearheads, spindle whorls, and fragments of pottery, bones and teeth of the bison, rhinoceros, cave bear, and horse.

RUSSIA.

Russia is represented by a small collection of crude chisels, arrowheads, spearheads, and flakes of slate, and quartzite schist from Vladivostok, fragments of pottery, decorated with cord impressions, from Novgorod, and other pottery fragments, one containing car-

[8] Axes and hammers pierced for the reception of a handle, and thus approaching in character corresponding iron implements in use at present, were for the most part manufactured from varieties of greenstone (diorite or diabos), basalt, or granite and similar rocks. Pierced implements of flint do not occur, as the hardness of this kind of stone rendered the drilling process difficult. Two different methods at least seem to have been employed in drilling. One with a hollow, cylindrical or tubular drill, probably of oxhorn or hollowed-out deerhorn aided by sand. This is evidenced by the presence of cores or lumps often left in the perforations. The other was done with a solid drill, probably of wood, operated by a bow drill, similar to that used in producing fire. In either method hard sand and water were applied. In some cases the hole on both sides tapers toward the middle, having the form of an hourglass, due to drilling from both sides with a solid point. In some rare instances the perforation is oval instead of round. The drilling was undertaken after the stone had been ground into the proper shape, as shown by many specimens with unfinished borings. The more finely finished specimens were probably not used as tools but as weapons, or, more likely, as badges of rank or command by chiefs, as the edges of the axes are usually too blunt for cutting purposes, and all of them, though sometimes expanded at the perforated part, would easily break at the shaft hole by hard usage.

bonized human bones from a tumulus near Chernigov. From tumuli in the neighborhood of Kiev in southern Russia (Ukraine) came a collection of rudely decorated pottery, bone ornaments, fragments of wood, pieces of charcoal, scoria, ochre, and baked earth.

SCANDINAVIA.

There may be first noted a collection from the Danish kitchen middens. The kitchen middens (*kjokken moddings*) are heaps of shells, principally those of the oyster, scattered along the Danish coast. They are accumulations of kitchen refuse of the peoples who lived on these sites and fed largely on shellfish and such animals as could be procured by hunting. These refuse heaps formed in course of time large mounds. Over 150 of these heaps are known in Denmark, sometimes 10 feet in height and nearly 350 feet in length.

The industrial remains usually found embedded in these mounds consist of roughly chipped flint implements, a few pointed implements of bone and horn, and some coarse pottery. The typical flint implement of the kitchen middens is the so-called tranchet, a wedge-shaped hatchet, usually made by transversely dividing a large oblong flake, having one straight, incisive lateral edge, into two or more sections. One end of each chisel-like section retains the sharp edge of the original flake, which is usually left untouched, while the sides and top are chipped into shape for hafting.

The animal bones found in the shell heaps are chiefly those of the stag, roe deer, and wild boar. The long bones have been broken to extract the marrow, which shows that the people of these settlements lived in part on the products of the chase. They appear to have had no knowledge of agriculture, and their only domestic animal was the dog.

It is generally supposed that the kitchen middens of Denmark represent one of the earliest stages of the Neolithic period and that they contain the oldest traces of man in the Scandinavian Peninsula, where, thus far, no remains of a Paleolithic industry have been found.

The remains from the kitchen middens include flint flakes, tranchets, points, chisels, hammerstones, and cores, bones of the red deer, roe, boar, and domestic dog, besides shells, fishbones, and bones of birds.

From a later phase of the Neolithic period both Sweden and Denmark are represented by considerable collections of finely worked stone implements, both chipped and polished, such as celts, perforated axhammers, square chisels, gouges, lunate knives and saws, daggers and spearheads, arrowheads, various bone implements, spindle whorls, and pottery fragments.

Remains of the Stone Age from Asia.

INDIA.

From India there is a collection of Paleolithic implements of quartzite corresponding to the Chellean and Acheulean hand axes of Europe. They were washed out of Pleistocene laterite (red ferruginous clay) alluvium containing quartzite bowlders in the districts of Boondi and Gazeepet, Madras Presidency. Polished celts and chisels of basalt and trap rock come from the Banda District, Northwest Province. A small collection of bone fragments of pig, vertebræ of fish, shells, and pottery fragments hail from the Andaman Islands in the Bay of Bengal.

There is also a large collection of minute chipped implements, found by A. C. Carlyle, formerly of the Archaeological Survey of India, in the caves and rock shelters of the Vindhya Hills, Central India. The implements, varying in size from half an inch to one and a half inches, are made of a variety of siliceous rock—jasper, chert, hornstone, flint, agate, and chalcedony—and in various forms, as crescentic, rhomboidal, trapezoidal, quadrilateral, triangular, and slender-blade form. These "pygmy tools" have been found in widely separated parts of the world and are generally attributed to the Neolithic period. Various uses have been ascribed to them, such as that of arrowheads, fish snags, lateral barbs of harpoons, or piercers. But they may have had various uses. Few of them show any signs of wear.[9]

CAMBODIA, INDO-CHINA.

The objects from Cambodia were found in the shell heaps or kitchen-middens, situated near the shores of Lake Ton-le-sap, which have been explored by Prof. L. H. James. The shell heaps, varying in depth from 13 to 29 feet, and covered by deposits of alluvial soil, the deposit of annual floods, are composed of three layers marking three different cultures. The upper layer, which was also the thinnest, contained bronze implements and ornaments together with some finely worked stone implements, and pottery decorated with geometrical designs characteristic of the Bronze Age. In the middle stratum were found objects of stone mixed with those of copper and bronze, which may be assigned to the transition period from the use of stone to that of metal. In the lower and deepest stratum were embedded stone implements and pottery characteristic of the Neolithic phase of culture.

[9] Compare Thomas Wilson, Minute Stone Implements from India, Report of the U. S. National Museum for 1892, pages 455–460.

From the size of the shell heaps, which must have required a long period for their accumulation, and from the fact that some of them are more than 50 miles distant from the great lake, so that at the time of their formation the margin of the lake must have extended to the site of the shell heaps, it is inferred that the Neolithic period was of exceptionally long duration in this region.

The collection consists of polished celts and chisels, rectangular and squared with square tangs for hafting. The slight thickness of these implements as also the poor quality of the stone (shale and feldspar) would indicate that they were intended not for practical use but for ceremonial or ritual purposes. It includes finely polished gouges, tubular and flat rings of black stone and a variety of ornaments—rings, bracelets, anklets, perforated beads made of shells belonging to the genera *Tridacena* and *Hippopus*, besides bone implements and ornaments, perforated animal teeth, clay cones and cups.

PALESTINE.

Palestine is represented by a collection of flint celts of the Chellean type, found near Raphaim, Neolithic flint chisels and flake tools found near Jerusalem, and flint flakes, representing the section of two flint sickles, showing polish from use, found near Gezer.

TROY.

The site of ancient Troy, the modern Hissarlik, in the northwest corner of Asia Minor, was explored by Dr. Henry Schliemann (1822–1890) during the years 1870 to 1882. He laid bare the remains of a series of ancient settlements one above the other. The collection here exhibited was found by him at various depths. It was presented to the National Museum by Mrs. Schliemann in 1893.

The collection includes polished celts and chisels of basalt, hammerstones and rubbing stones, bone implements, terra-cotta balls and weights, ivory plaques, probably representing idols, a number of characteristic pottery vessels and some bronzes.

JAPAN AND KOREA.

The remains of the Stone Age in Japan are chiefly found in shell heaps, resembling the kitchen-middens of Europe. They occur near the coast, and in those parts of the islands which had been inhabited by the ancestors of the Ainos who occupied Japan long before the modern race of the Japanese. Most of the stone implements consist of roughly worked slate; but there are also some well-finished, polished celts, so that no dividing line between Paleolithic and Neolithic can be drawn. The numerous remains of handmade pottery, in fragments as well as in almost perfect vessels, would indicate that

this whole culture was Neolithic. The stone implements include, besides hatchets, knives, arrowheads, and drills. Especially characteristic are the "thunder-mallets," or "stone-mallet-swords," and the crescent-shaped knives with projecting knob at the butt or back, probably designed to afford a hold in binding it to a thong.

The personal ornaments appear in shape of stone and clay rings, beads, and comma-shaped objects, called *magatama* ("crooked jewels"). The pottery decorations show great variety in form and motive.

The bones occurring most frequently are those of the deer, boar, fox, bear, and, occasionally, dog, wolf, and monkey. Human bones are found in the shape of fragments of the tubular bones, such as the humerus, radius, ulna, etc.

The small collection from Korea includes rude celts and chisels of trap rock, polished celts of quartzite, polished and carved daggers and spearheads of shale, polished arrowheads, semicircular knives, notched, or hour-glass-shaped implements, amber beads, and "crooked jewels."

Remains of the Stone Age From Africa.

EGYPT.

Most of the Egyptian stone implements have been picked up upon the surface of the desert where relics of various ages are found mingled, and as a rule there is little to determine their age other than their form and the condition of their surface, as no animal remains belonging to species now extinct have thus far been found in an undisturbed stratum in Egypt. But it is commonly agreed that the northeast corner of Africa was occupied by man at a very remote period. The implements resembling those found in the river-drifts of Europe may therefore be referred to an early age, while the finely chipped implements, such as knives, lance-heads with ripple flaking and serrated edge, etc., which are in delicate workmanship only comparable with the Neolithic products of Scandinavia, may be assigned to the period immediately preceding the dawn of history.

The use of stone implements in Egypt was not confined to the prehistoric period, but was continued for domestic and ceremonial purposes into historical times.

The considerable Egyptian collection comes largely from the province of the Fayum, west of the Nile, from the ancient quarry sites and workshops in the Wady el-Sheikh, east of the Nile, opposite el-Fent, Middle Egypt, and from the Valley of the Kings. The collection includes a large number of rude bladelike implements, triangular, pyramidal, leaf and lozenge-shaped, some with one edge curved

or convex, the other straight, assuming a lunate form. Some are rudely chipped on both edges, others on one edge only. They were found on the surface, around shallow pits from which the chert had been extracted. Many of them have been broken in the manufacture, and the two fragments have often been exposed to the weather and the rays of the sun on opposite faces, so that when joined together they show different degrees of patination. Then flake tools, celts, chisels, gravers, Mousterian scrapers and points, side scrapers, gravers, shouldered knives, sickles and saws, arrowheads, spearheads, crescent-shaped implements, etc.

ALGIERS.

From Algiers in North Africa there are only a few flakes and cores, shell beads, fragments of bones and of pottery.

SOMALILAND.

The collection from Somaliland in East Africa comprises chipped celts, scrapers, points, knives, etc., of quartzite. The form of the larger implements is very similar to that of those from the river gravels of Europe (The Chellean and Acheulean hand-axes or bouchers), while the smaller implements, mostly points, resemble the Mousterian equivalents.

SOUTH AFRICA.

The collection from South Africa (Cape Colony and Transvaal) consists of a variety of flake tools, celts of the Acheulean type, digging and rubbing stones, pottery fragments, and human bones.

AUSTRALASIA.

It is generally assumed that man came at a very early time to Australia. The original inhabitants known to history were related to the Melanesians, as also to the Negritos of the Andaman, Moluccas, and Philippine Islands. The now extinct Tasmanians represented the last remnant of these primitive aborigines. The present Australian natives came later and drove out the aborigines to the adjacent islands.

At the first arrival of white men in Australia, in 1788, when they established in the neighborhood of Port Jackson a penal colony, the natives were estimated to number 150,000. In 1891 they had dwindled to 30,000. They usually live in hordes not exceeding a hundred members. Occasionally these hordes coalesce into tribes. When left to themselves they continue to live in the Stone Age. Their principal occupation is hunting. Their implements consist of stone axes, knives, scrapers, chisels, and saws, all roughly made and

corresponding closely to the Paleolithic forms, though occasionally polished. They also employ bones, shells, and wood for the manufacture of tools, and make simple baskets.

The collection in the National Museum consists of polished and partly polished celts of lava and trap rock, a spearhead of quartzite, rude points and scrapers, chips, and bones of a dog.

TASMANIA.

Tasmania is an island of Australasia in the southern ocean, 150 miles south of the colony of Victoria, from which it is separated by Bass Straits. It is a British colonial possession and has an area of 26,216 square miles. It is named after the Dutch navigator, Abel Janszoon Tasman, who discovered it in 1642.

The aborigines became extinct in 1876, except a few half-castes who survive. They remained in the lowest stage of culture, lower even than that of the Paleolithic man of Europe. They lived on the chase of animals, which they roasted whole in the skin, and on shellfish, which they obtained by diving. Cooking by boiling and the art of fishing by hook or net were alike unknown to them. They wielded a wooden spear and a sort of knob berry. Fire was obtained by stick rubbing. They had rafts, or floats, but no boats. Their fundamental stone implement was a hand-grasped rude knife, or scraper, generally chipped only on one side and quite devoid of symmetry. The long cutting implements, characteristic of the stone industry, both of the Paleolithic and Neolithic periods of Europe, are absent. Next to these most primitive implements, and used for cutting, scraping, sawing, chopping, etc., may be mentioned the anvil, a chipped round stone plate upon which the animal bones were broken to extract the marrow, using another stone as a hammer. Flint being unknown in Tasmania, the aborigines used a fine-grained sandstone or phthanite, which is not as tractable as flint, and this may partly account for the limited variety of the stone implements of the Tasmanians and the inferiority of the workmanship.

The collection includes a hammer and anvil, cores, knives, and scrapers.

Ancient Bronzes.

Bronze antiquities belong to the period when stone was gradually falling into disuse, and iron was either practically unknown or only partially adopted for tools and weapons. The beginning and duration of this period varied in different countries, and was overlapped by the stone age on the one side and by the iron age on the other. No two prehistoric periods can be separated by a hard

and fast line, and the terms "Stone Age," "Bronze Age," and "Iron Age" denote rather stages of human culture than divisions of time. In a general way it is assumed that the use of metal, which constitutes one of the most important steps in human progress, began 3000 to 4000 B. C.

The oldest piece of bronze so far known is a rod found in the pyramid of Medum, Egypt, which is held to date from 3700 B. C., while Babylonia can show a bronze statuette of Gudea from about 2500 B. C. The beginning of the Bronze Age in Europe is set in the period between 200 and 1800 B. C.

By the word "bronze" is designated in archeology a mixed metal composed chiefly of copper with an alloy of tin, the latter ranging from 20 to 9 per cent. Besides copper and tin there are found in ancient bronzes appreciable quantities of silver, gold, and zinc, although the alloy of copper and zinc, known as brass, was almost unknown in antiquity.

It is probable that in some parts of the world copper was the first metal of which implements were made, and that its use may have continued for some time before it was discovered that the addition of a small portion of tin not only rendered it more readily fusible but added to its elasticity and hardness. But there is no evidence of a "copper age," or of a universal stage of culture characterized by the sole use of copper. There is also no doubt that gold was known in some parts of Europe in the Neolithic Age, and it may possibly have been the first metal worked in this part of the world.

The use of bronze was far more extensive and varied in ancient than in modern times. It was employed not only for decorative purposes, but also in the manufacture of furniture, household utensils, armor, and other objects.

Several processes were employed by the ancients for the production of works in bronze: For implements and utensils, hammering and casting; for statues, solid casting, beaten plates riveted or welded together, and hollow casting; for reliefs and decorative work, chasing, and repousse work.

The collection of bronzes in the museum comprises tools, as celts in their four principal forms, viz, flat, flanged, winged, and socketed celts, chisels, knives, razors; weapons, as swords, spearheads and arrowheads; domestic utensils, as pitchers, pails, bowls, dishes, lamps, strainers, ladles, cups, scales, etc.; chirurgical instruments; ornaments, as fibulae, finger rings, earrings, bracelets, anklets, mirrors, ets., besides masks, helmets, stamps, human and animal figurines, etc.

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THE ARCHEOLOGICAL COLLECTION OF HISTORIC TIMES.

(For a more detailed description of some of the important specimens see the section "Guide to the Collections of Old World Archeology").

EGYPTIAN ANTIQUITIES.

The remains of ancient Egypt are chiefly of a sepulchral character. The collection in the National Museum includes a human mummy and several mummified animals. Several coffins, funerary boxes and cones, a considerable number of ushabti figurines, a set of Canopic vases, a Greco-Egyptian painting, Greco-Egyptian inscribed papyri, a collection of mummy cloth, necklaces, scarabs, amulets, pottery ranging from the predynastic times down to the Greco-Roman period. The later Christian period is represented by a collection of Coptic cloth. Of sculpture there are an original stone sphinx and casts of statues and busts of the chief divinities and the great historic rulers, besides reliefs. Facsimiles of the Book of the Dead, casts of the Rosetta and Canopus Stones, squeezes from the tomb of Taia, etc.

BABYLONIAN AND ASSYRIAN ANTIQUITIES.

They consist mainly of casts of sculptures including the Code of Hammurabi, the torsos of Gudea, a stele of Sargon, human-headed winged lion and bull, the black obelisk of Shalmaneser II, a boundary stone, besides many reliefs representing genii before the sacred tree or tree of life, hunting and war scenes, and a collection of seals.

HITTITE SCULPTURES.

In the Bible the Hittites are derived from Heth, son of Canaan, the son of Ham (Genesis x, 15). They are described as an important tribe in the region of Hebron (Genesis xxiii, 2), and are often mentioned as one of the seven principal Canaanitish tribes, and sometimes as comprising the whole Canaanitish population (Joshua i, 4). From Abraham (Genesis xxiii) to Solomon the Hittites came more or less in contact with Israel. Numbers of them remained with the Jews even as late as the time of Ezra and Nehemiah (Ezra ix, 1). Hittite kings are mentioned as living north of Palestine (I Kings x, 29; II Kings vii, 6), and some writers call them Syrian Hittites to distinguish them from the Canaanite tribe. Recently the Hittites have been identified with the *Kheta* of the Egyptian and *Khatti* of the Assyrian monuments.

From the inscriptions on these monuments it is gathered that this people at an early period were a mighty power, ruling for a time the territory from the Euphrates to the Ægean, and being a rival of Egypt and Assyria.

Of late there have been added to the Biblical, Egyptian, and Assyrian sources numerous monuments which were discovered throughout Asia Minor and northern Syria. These monuments, mostly of black basalt, contain representations in bas-relief of religious objects, winged figures, deities standing on various animals, sphinxes, griffins, the winged disk, as symbols of the deity, the two-headed eagle (which became the standard of the Seljukian Turks, and afterwards of Austria and Russia), and hieroglyphic inscriptions in lines alternating from right to left and left to right, called *bustrophedon*, besides inscriptions in the cuneiform characters of Assyria and Babylonia. The foremost center of Hittite power was at modern Boghaz-Keui, in Cappadocia, Asia Minor, where in 1906 remains of palaces and an archive of clay tablets inscribed in Babylonian characters were discovered.

The casts from the Hittite reliefs in the Museum collection include divinities, kings, warriors, sphinxes, griffins, composite beings, and scenes from the chase.

PERSIA.

Persia is represented by casts of the inscription and the warrior from Persepolis.

SYRIA AND PALESTINE.

The antiquities from Syria and Palestine may be designated as "Biblical Antiquities." They include casts of some of the inscriptions found in Palestine, as the Moabite Stone, the Siloam inscription, and the Temple stone; also objects illustrating Biblical passages, as millstones, sling, trap, and various ornaments; a collection of coins from Bible lands; precious stones and musical instruments mentioned in the Bible. Also a few specimens of the geology and flora of Palestine, a large relief map of Palestine and casts of the colossal statue of the god Hadad and of the torso of King Panamu II from Syria.

ARMENIA.

The territory which once formed the kingdom of Armenia is the table-land situated between Asia Minor and the Caspian Sea, inclosed on several sides by the ranges of the Taurus and Anti-Taurus, and partly traversed by other mountains, the highest of which is the volcanic peak of the Ararat mentioned in the Old Testament.

The collection from Armenia, which consists of pottery, bronze torques, bracelets, pendants, pins, shell beads, iron spearheads and knives, was obtained from the ancient necropolis of Monci-veri, near Allahverdi in the Caucasus.

TURKESTAN.

From Turkestan, Central Asia, there is a collection of pottery and fragments of tiles, dating from the eleventh and twelfth centuries, A. D.

TEREK, CAUCASUS.

The collection, which was taken out from a tomb near Terek, consists of copper and bronze pieces—pins, rings, bracelets, anklets, buckles, and fragments of handles, etc.—colored glass beads, and pottery fragments.

GRECO-ROMAN ANTIQUITIES.

The collection comprises a set of casts of statues and busts of the major and minor divinities of the Greco-Roman pantheon. A wooden model of the Parthenon. Casts of reliefs illustrating some episodes of Greek mythology, as the battle of the gods with the giants and of the Centaurs with the Lapithi, etc. A Roman mosaic from Carthage. Reliefs from the Triumphal Arch of Trojan at Beneventum. Votive tablets and sepulchral stellae. Plaster casts and electrotypes of engraved gems. The minor or domestic arts are represented by a collection of painted pottery and terra-cotta figurines.

GREEK AND ITALIAN POTTERIES.

The manufacture of vases was an important industry in early prehistoric times in Greece and on the adjacent islands of the Archipelago.

The potteries found on the site of ancient Troy (modern Hissarlik, Asia Minor) are still crude, mostly handmade and unpainted, and often in the shape of a rudely modeled human figure.

In the vases of the "Mycenaean civilization" (about 1500 to 1000 B. C.), so called after the city of Mycenae, which was its center, artistic feeling begins to appear. The vases are all wheel made and varied in form and decoration. The favorite designs are bands and spirals, plants, leaves, and marine animals (cuttlefish, octopuses, etc.).

Next follow the geometric pottery, in which the decoration is composed of patterns in lines on a regular plan and measurements, such as zigzags, meanders, and concentric circles. The most interesting and important variety of this style is the pottery, painted with naval battles and funeral processions, found in the cemetery near the Dipylon (double gate) of ancient Athens and hence called Dipylon vases. This style of decoration prevailed from about 1000 to 800 B. C.

About the middle of the eighth century, B. C., the "orientalizing" style came into vogue, characterized by an ornamentation in bands or zones, recalling that of Oriental carpets. The vases so treated are called "Corinthian." The ground is light yellow or cream colored; the conventionalized figures between the bands are reddish-brown, heightened with white, black, and violet; flowers, leaves, and rosettes are scattered over the ground.

The height of development was reached in the sixth and fifth centuries B. C., in the vases produced in Attica, Greece. According to the disposition of the colors, two styles were distinguished in the painting of the potteries of this period—the "black-figured" and the "red-figured" style. In the former, which lasted till about the year 500 B. C., the designs were (silhouettelike) on red ground; in the latter the design stood out in red color against the black glaze which covered the remaining surface of the vase. These two kinds of vases are sometimes called "Etruscan" because great numbers of them have been found in the tombs of Etruria, but it seems certain that nearly all of them were made in Greece, at least in the fifth century, and that all the finer vases discovered in Etruria are of Athenian origin.

The subjects depicted on the vases illustrate Greek life in all its aspects: Myths of the gods, story and legend, the school and gymnasium, the stage and many scenes from everyday life. The chief forms of the vases are: Amphora, so called from its two handles, used to hold liquids as well as grain, and always egg-shaped in form; pelike, a development of the amphora, in which the foot is done away with and the body swells out from the handles downward; crater ("mixer"), used for mixing water with wine before serving it in cups to guests at banquets; oenochoë ("wine pourer"), used for dipping the wine from the crater and pouring it into goblets, also for pouring water on the hands of guests at banquets and for libations to the gods; kylix (chalice), the favorite drinking cup at banquets; hydria (water jar), used almost exclusively for carrying water, and provided with three handles—a large one at the back for carrying when empty and two smaller ones at the sides for carrying when full; skyphus, originally a wooden bowl used by the peasantry for milking, later made in metal and clay and used as a drinking cup, and sacred to Herakles (Hercules); aryballus, an oil flask used in the bath; alabastron, so called from the material of which it was originally made, generally used for ointments and perfumes in the toilet, but sometimes also for funeral purposes. Both the aryballus and the alabastron have a flat top with small orifice, and a globular or cylindri-

cal body. Lekythus, originally an oil flask, was chiefly used for funeral purposes.

In the fourth century B. C., important potteries were also established in southern Italy (Lucania, Apulia, and Campania), which in general followed Athenian models, though developing local variations of style. About the middle of the third century B. C. the manufacture of painted vases ceased, even in Italy. They were superseded by vases decorated with reliefs ("Megarian bowls" and "Arretine ware").

In the Museum's collection of pottery nearly all the forms enumerated above are represented and range in date from the seventh century B. C. to the first century A. D., including the Roman black vases (so-called *Buchero*) and the Arretine red ware (also incorrectly called "Samian"), which was a characteristic product of the Romans, deriving its name from Arezzo (the ancient Arretium) in Tuscany, Italy, the chief center of its manufacture.

Another collection of pottery, ranging in date from the middle of the second millenium to the end of the first millenium B. C., may be roughly assigned to the countries around the Mediterranean Sea, viz, Phenicia, Syria, Cyprus, Egypt, Greece, etc.

ANCIENT TERRA COTTAS.

Terra-cotta statuettes have been found on nearly all the famous sites of antiquity, from Babylonia to north Africa, and from Sicily to the Crimea in Russia. The earliest go back to the second millenium B. C., and their manufacture continued down to the end of the first century A. D. The subjects represented in these statuettes are: Figures of deities; mythological subjects; scenes from daily life; caricatures; masks, animals, and toys. Most of these represent female figures, seated or standing, with a high headdress, or with a veil or part of the upper garment drawn over the head. Sometimes they hold a child or carry an animal or fruit.

As these figurines have chiefly been found on sites of former sanctuaries or in tombs, it is assumed that they were originally intended for religious purposes, but in time lost this significance and were used by the Greeks as ornaments in daily life.

The Romans placed these statuettes in their house shrines, but employed them also as toys and gifts and for the decoration of their houses.

The earliest fabrics were modeled by hand and were solid. Subsequently molds were generally used which enabled the making of hollow and light figurines. The head and arms were usually molded separately and attached afterwards, which permitted variations to the figures coming from the same mold, so that no two are alike.

The final touches before firing were given the figure either with the finger or with a graving tool. After the firing the figures were colored, in rare cases, gilded. This has been largely worn off.

The most finished and elegant terra-cotta statuettes are those found in the graves of Tanagra, in Boeotia, Greece, dating from the fourth and third centuries B. C., examples of which, in facsimile, are shown in wall cases in the southeast end of the hall.

The bulk of the terra-cotta figurines in the collection represent female figures, some of them adorned with diadem or crown with an expression of dignity and calm, evidently meant for a goddess, others in various poses, sometimes holding a child or an animal. A small number are of male figures, satyrs, caricatures, and animals. The facsimiles of the Tanagra figurines largely represent mythological scenes.

TERRA-COTTA LAMPS.

Terra-cotta lamps have been found everywhere through the ancient domain of the Roman Empire, mostly in tombs where they were placed for the use of the dead, or with the idea of their burning perpetually. They were used for lighting houses, in processions, as offerings in temples, as New Year's gifts, and for funerary purposes.

The oldest lamps date from the third century B. C. and were made on the wheel, with decorations in incised lines; later they were either modeled by hand or made in molds, with decorations in relief.

The principal parts of the lamp are (1) the reservoir, which contained the oil, (2) the flat, circular top, (3) the nozzle with hole for insertion of the wick, and (4) the handle, which was not indispensable.

Wicks were made of a plant known as *verbascum* or *thryallis*, but tow and papyrus were also employed. The oil was vegetable oil of some kind.

The average size of the lamps is from 3 to 4 inches in diameter, with a length of about 1 inch greater than the diameter, and they are mostly about 1 inch in height.

The Museum's collection of terra-cotta lamps includes specimens from Egypt, Phenicia, Palestine, Cyprus, Greece, and Italy. The tops of some are adorned in relief with figures of Gods—Jupiter, Zeus with the eagle, Cupid in various postures, etc.—or with human figures, and there are some with the monogram of Christ.

ANTIQUE IRIDESCENT GLASSWARE.

Glass which has for many years been subject to the slowly disintegrating influences of dampness, alternating heat and cold, light, and darkness, etc., displays an iridescent play of colors, due to the forma-

tion in consequence of the decomposition of minute scales or films on the surface that reflect light in colors similar to the delicate hues on the neck of a dove or of soap bubbles.

The Museum's collection of ancient glassware comprises a large variety of vessels: amphoras, pitchers, cups, bowls, dishes, vases, bottles of various shapes, besides bracelets and beads.

ANCIENT ORIENTAL SEALS.

Seals among the ancient peoples served a threefold purpose: (1) to authenticate a document, as does the modern signature, (2) as talismans, and (3) as ornaments. The oldest form of seal is a cylinder. It had its origin in Babylonia, where it can be traced back in the fourth millennium B. C., while in Egypt it goes back to the first dynasties, but there was later superseded by the engraved scarab or beetle. The material of the seals varies from the hardest stones, as porphyry, quartz, hematite, rock crystal, to the soft marble, serpentine, alasbaster, as well as ivory and bone. The engraving, in intaglio, occupies the convex surface. The subjects engraved on them represent either episodes of ancient myths and legends or religious ceremonies. They are often accompanied by inscriptions. The cylinders are generally pierced longitudinally. Through the hole a metal axis was passed, by means of which it was rolled on the soft clay, which was the writing material in the valley of the Euphrates. In the time of the Assyrian Empire, in the seventh century B. C., the cone, usually of chalcedony or carnelian, begun to replace the cylinder seal. In the Persian period the cone seal developed into the hemispherical or flattened into the shape of a finger-ring.

The Museum's collection has nearly a hundred original seals, mostly cylinders, and upwards of three hundred flat casts.

COINS AND MEDALS.

The collection of upwards of 500 specimens comprises Greek coins, beginning with Alexander the Great, Roman coins of the Republic as well as of the Empire, Byzantine coins, Papal and other Italian coins, besides small numbers of Carthaginian, Armenian, and Mohammedan coins.

ORIENTAL TILES.

The collection, which comes from Turkey and Persia, consists of glazed, enameled, and inlaid tiles and plaques.

COLLECTION OF BIBLES.

The collection includes editions of the Scriptures in the original tongues; facsimiles of the manuscripts of the old versions; several English versions; and translations in modern foreign languages.

GUIDE TO THE EXHIBITION.[10]

The collections of Old World Archeology are installed in the elongated hall on the west side of the second story of the north wing of the Natural History Building and the entire outer end or pavilion of the wing, occupying about 7,926 feet of floor area. The pavilion is mainly occupied by antiquities of Egypt and Babylonia. (pls. 1–3).

1. Wall case on the east side of the pavilion, containing Egyptian coffins and sepulchral boxes. The coffins are made in form of a mummy, of planks, covered with a thin layer of plaster, upon which are painted mythological scenes, figures of the gods, scenes of the nether world, etc. Sepulchral boxes, made of wood, were placed in the tomb to hold sepulchral figures (*ushabti*), papyri, articles of dress, the toilet, and other things. They vary in size from 6 to 8 inches to 2 feet in length. Some are perfectly square, others oblong in shape, and each end rises above the level of the cover. Some have two, and others have three or four divisions. The outsides are usually ornamented with scenes of worship and figures of the gods (pl. 4).

On the wall over the case is an Assyrian bas-relief[11] representing four warriors with spears and shields; on the north side, another Assyrian bas-relief representing a winged figure holding cone and bashed and a eunuch, with an inscription of Ashurnazirpal, King of Assyria, 884–860 B. C., while on the south side are three Egyptian bas-reliefs, representing, respectively, a female bust, two heads of Asiatic captives from Medinet Habu and Rameses III, the second king of the xxth dynasty (about 1180 B. C.).

2. Egyptian mummy in its coffin. Found at Luxor, Egypt, in 1886. Length, 5 feet 6 inches. No hieroglyphics or inscriptions exist either on the mummy or coffin. The face and head are covered with a mask of green cement; the body is delicately proportioned. On the chest lie four small tablets about the size of playing cards, each one having a mummied figure of the god Osiris in a standing position. Two shield-shaped ornaments lie across the breast and stomach, respectively. The upper one bears the sacred beetle (*scarabaeus*) with spread wings, beneath which is the *tet* (emblem of Osiris, also designated as nilometer) between two figures, which support each the sun disk upon the head. At the end of the wings is represented the hawk head of Re, also supporting the sun disk. Over

[10] Part of the collection relating to Bible lands has been described in a bulletin entitled "Biblical Antiquities: A Description of the Exhibit at the Cotton States International Exposition, Atlanta, 1895. By Cyrus Adler and I. M. Casanowicz. Report of the U. S. National Museum for 1896, pp. 943–1023, with 46 plates."

[11] If not otherwise stated the sculptures described in this pamphlet are casts.

the surface of the shield are painted representations of jewelry (necklaces). On the lower shield appears the kneeling figure of the goddess Nephthys, with extended arms and wings. On either side of her head are two groups of three small figures each. Ostrich plumes appear in the corner of the shield. Along the legs is a sheet of cemented linen, on the top of which is a mummy on a dog-shaped bier; at the head of the bier is a figure kneeling, holding plumes. Further down is a second *tet*, on either side of which a figure with an implement in each hand faces two mummied figures. The feet of the mummy are incased in a covering of cemented linen.

The ancient Egyptians conceived man as consisting of at least three parts: the body, the soul, and the *Ka;* that is, the double or genius. The *Ka* was supposed to remain in existence after death and to be the representative of the human personality. In order that the *Ka* might take possession of the body when it pleased, the latter had to be preserved from destructive agencies and decay in the tomb. To this end the Egyptians mummified their bodies, built indestructible tombs, inscribed the tombs and coffins with magical formulae to repel the attacks of demons, and placed statues, household goods, food, statuettes of servants, etc., in the tomb that "the house of eternity" might as much as possible resemble the home of the deceased.

To arrest the decomposition of the body, the Egyptians embalmed it by means of bitumen, natron, and various drugs or spices. The name given to a body thus preserved was *mummy*, derived from the Arabic (?) word for bitumen, "*mumia*," and "*mumiyya*," "bitumenized thing." The native Egyptian names for mummy are *sahu*, or *ȳes*, "to bandage a dead body." The process of mummifying was of great antiquity in Egypt, probably dating back to the earliest dynasties; it reached the highest perfection at Thebes during the eighteenth and nineteenth dynasties (about 1600 to 1200 B. C.), and the practice is said to have continued to 500 A. D.

The Greek writers Herodotus (ii, 85) and Dioderus Siculus (i, 91) record that the Egyptians employed three methods of embalming, more or less elaborate, according to the wealth and position of the deceased. The most costly mode is estimated at a talent of silver, or about $1,250. After removing the brain and viscera the cavities of the body were rinsed with palm wine, filled with myrh, cassia, and other aromatics, and soaked in natron (subcarbonate of soda) for 70 days. It was then washed, swathed in linen bandages, and smeared with gum. The second mode cost 20 *minae*, about $300. The intestines were allowed to be dissolved by means of cedar oil injected into the abdomen, while the flesh was conserved by natron, in which the body was soaked for the prescribed period.

The third method, employed by the poorer classes, consisted in merely soaking the body in natron. The Biblical record mentions embalming only in connection with the Egyptians, the bodies of Jacob and Joseph, who died in Egypt, having been thus preserved. (Genesis L, 2–25).

EGYPTIAN FUNERAL PROCESSION AND BURIAL.

The coffin containing the mummy was carried to the bank of the Nile in a boat placed on a kind of sled drawn by oxen, and was escorted by priests, mourners, wailing women, and attendants bearing funeral furniture, offerings, etc. The procession embarked and in a short time arrived at the western banks, in the highlands of which the Egyptians usually built their cemeteries, as they imagined the entrance into the hidden land lay in the west where the sun disappeared. Here the procession was re-formed and continued its way to the bluffs opposite Thebes. When the procession arrived at the tomb the mummy or a statue of the deceased was placed in an upright position before the door. Tables loaded with offerings of cakes, beer, fruit, flowers, etc., were laid before it, and a bull was slaughtered, from which an attendant cut off one of its haunches and held it to the nose of the statue. One of the priests performed the ceremony of "opening the mouth," touching the mouth and eyes of the mummy with iron instruments, in order that the deceased might regain the use of his intelligence and limbs which he lost by the process of embalming. During these ceremonies another priest recited the portions of the funeral ritual appropriate to each act from a roll of papyrus. After the slaughter of another bull and the presentation of a number of offerings the funeral ceremony was complete (pls. 5 and 6).

3. Screen. On the east side the screen bears a large relief map of Palestine. The map is the result of geographical and geological survey work, carried on for more than 10 years by experts in the service of the Palestine Exploration Fund, and is made on the scale of $\frac{1}{1\,8\,8\,9\,6\,0}$, or three-eighths of an inch to the mile. It embraces the whole of western Palestine, from Baalbek in the north to Kadesh Barnea in the south, and shows nearly all that is known of the country east of the Jordan. The natural features of the country stand out prominently, being reinforced by appropriate colors. The mountains and plains are shaded a creamy white. The seas, lakes, marshes, and perennial streams are shown in blue. The Old and New Testament sites are marked in red. The map thus furnishes a most important aid for the understanding of the Bible narrative.

The west side of the screen is occupied by the Siloam inscription and the Greek inscription from the Temple of Jerusalem.

The Siloam inscription was discovered in 1880. It is engraved on a recessed tablet cut in the wall of the tunnel a few yards from its lower end. The latest restoration and translation [12] is as follows:

> The boring through (is completed). And this is the story of the boring through. While yet they (plied) the drill, each toward his fellow, and while yet there were three cubits to be bored through, there was heard the voice of one calling unto another, for there was a crevice in the rock on the right hand. And on the day of the boring through the stonecutters struck, each to meet his fellow, drill upon drill; and the waters flowed from the source to the pool for a thousand and two hundred cubits, and a hundred cubits was the height of the rock above the heads of the cutters.

The inscription is not dated, but the tunnel was probably constructed in the reign of King Hezekiah and is referred to in II Chronicles xxxii, 4 and 30, as follows: " So there was gathered much people together, and they stopped all the fountains and the brook that flowed through the midst of the land saying, Why should the King of Assyria come and find much water? * * * " This same King Hezekiah also stopped the upper spring of the waters of Gihon, and brought them straight down on the west side of the City of David.

The original is preserved in the Museum of Constantinople, Turkey.

The stone containing the inscription from the Temple was discovered by the French archeologist, M. Clermont-Ganneau, May 26, 1871. The inscription reads: " No stranger is to enter within the balustrade round the temple and inclosure. Whoever is caught will be responsible for his death which will ensue." The inscription throws light on the incident in Acts xxi, 28–31, where Paul was accused of bringing Trophimus, an Ephesian, within the balustrade.

The original is in the Museum of Constantinople, Turkey.

Both the map and the inscriptions are surrounded by a series of geographical and ethnographical photogravures, showing various sites and human types of Palestine.

4. Flat-top table case. Contains a selection of Oriental seals, originals as well as flat cast, for which see above, p. 444. On the bottom of the case are some Egyptian antiquities.

The center of the Pavilion is occupied by a mosaic, flanked on either side by two monuments on bases.

5. The Moabite Stone. In II Kings iii, 4 ff. it is related that Mesha, the King of Moab, had paid tribute to the Kings of Israel, but after the death of Ahab he rebelled. Thereupon Ahab's son, Joram, allied with Jehoshaphat, King of Judah, invaded Moab and

[12] See George A. Barton, Archaeology and the Bible, Philadelphia, American Sunday-School Union, p. 377.

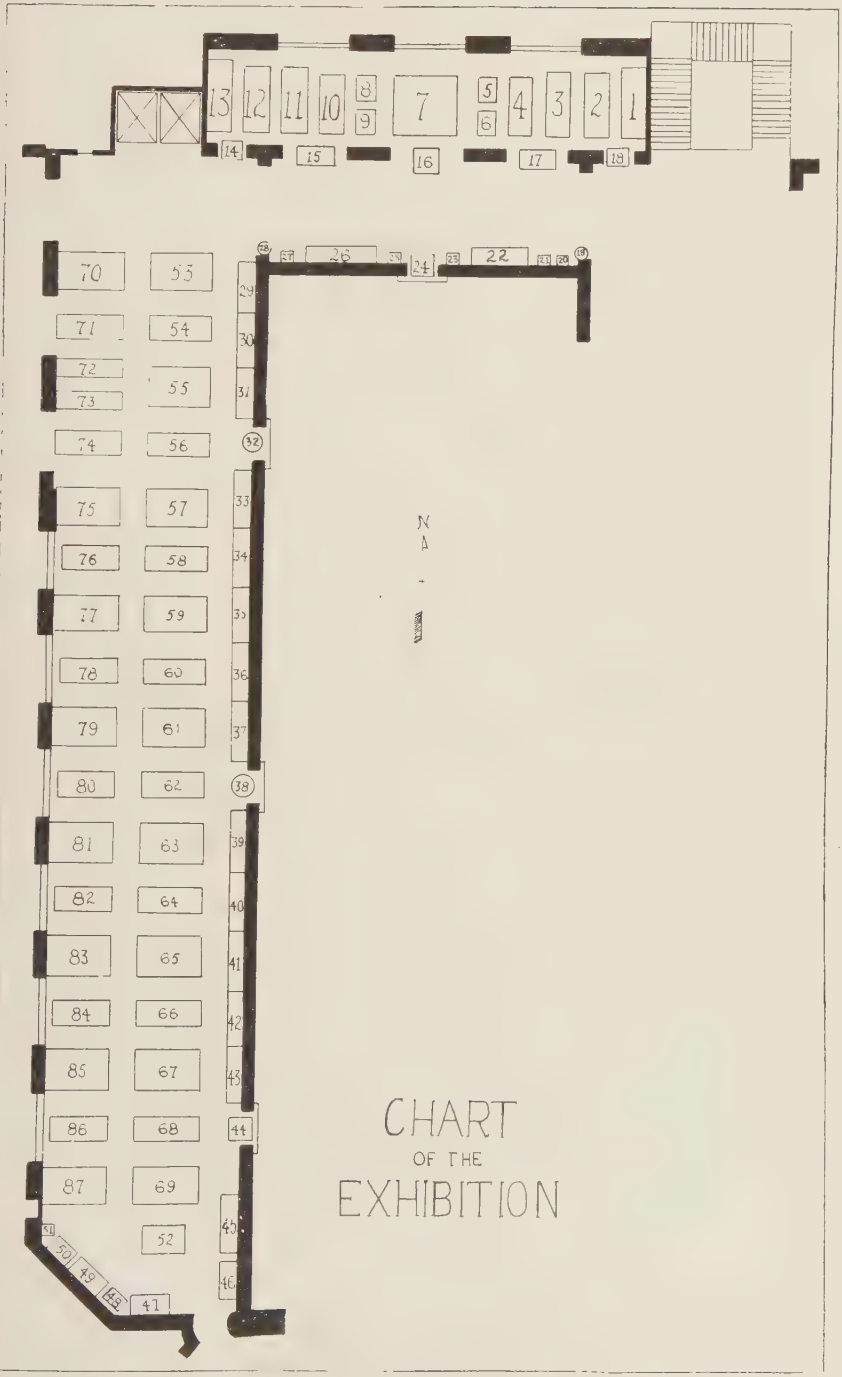
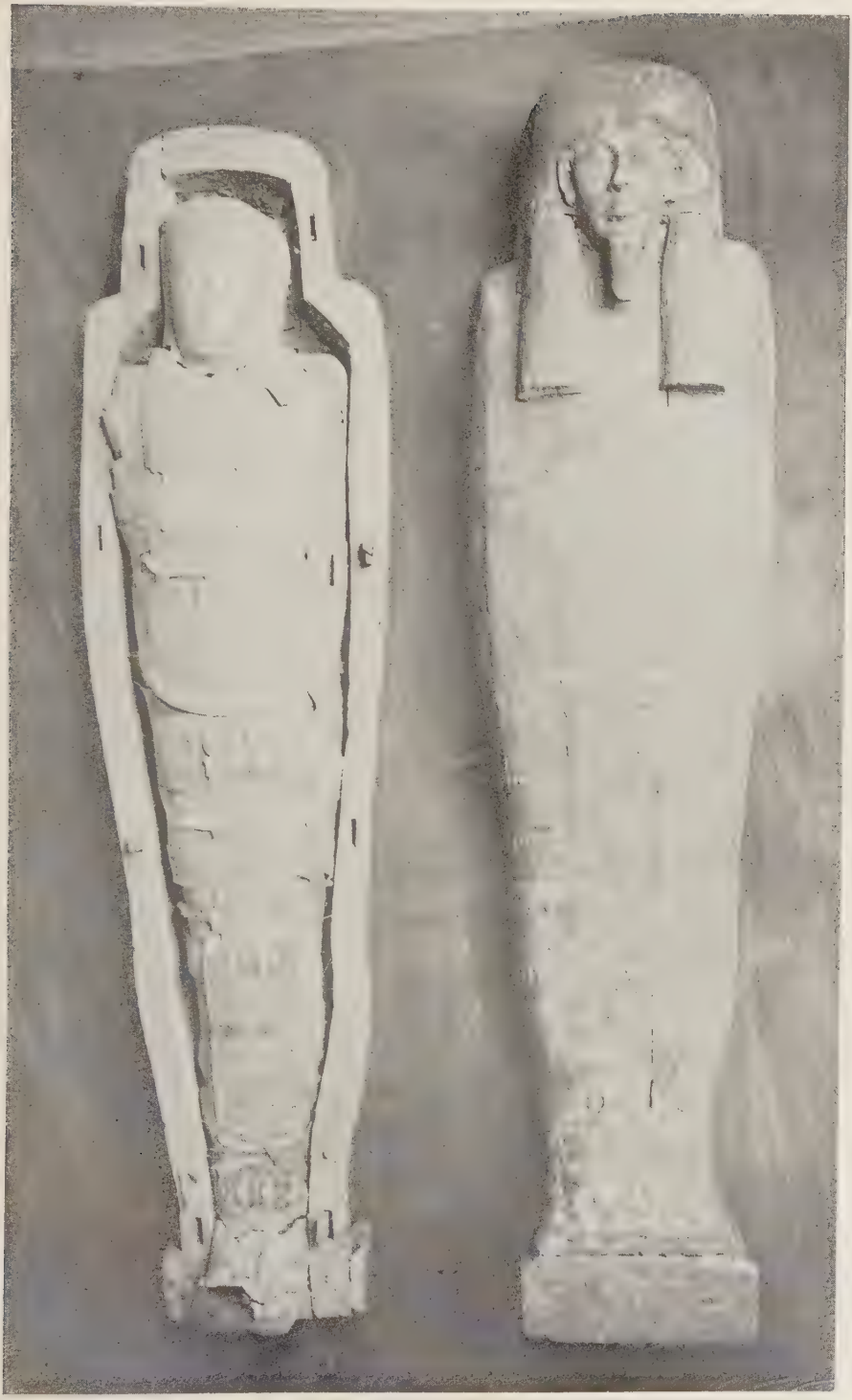


CHART
OF THE
EXHIBITION

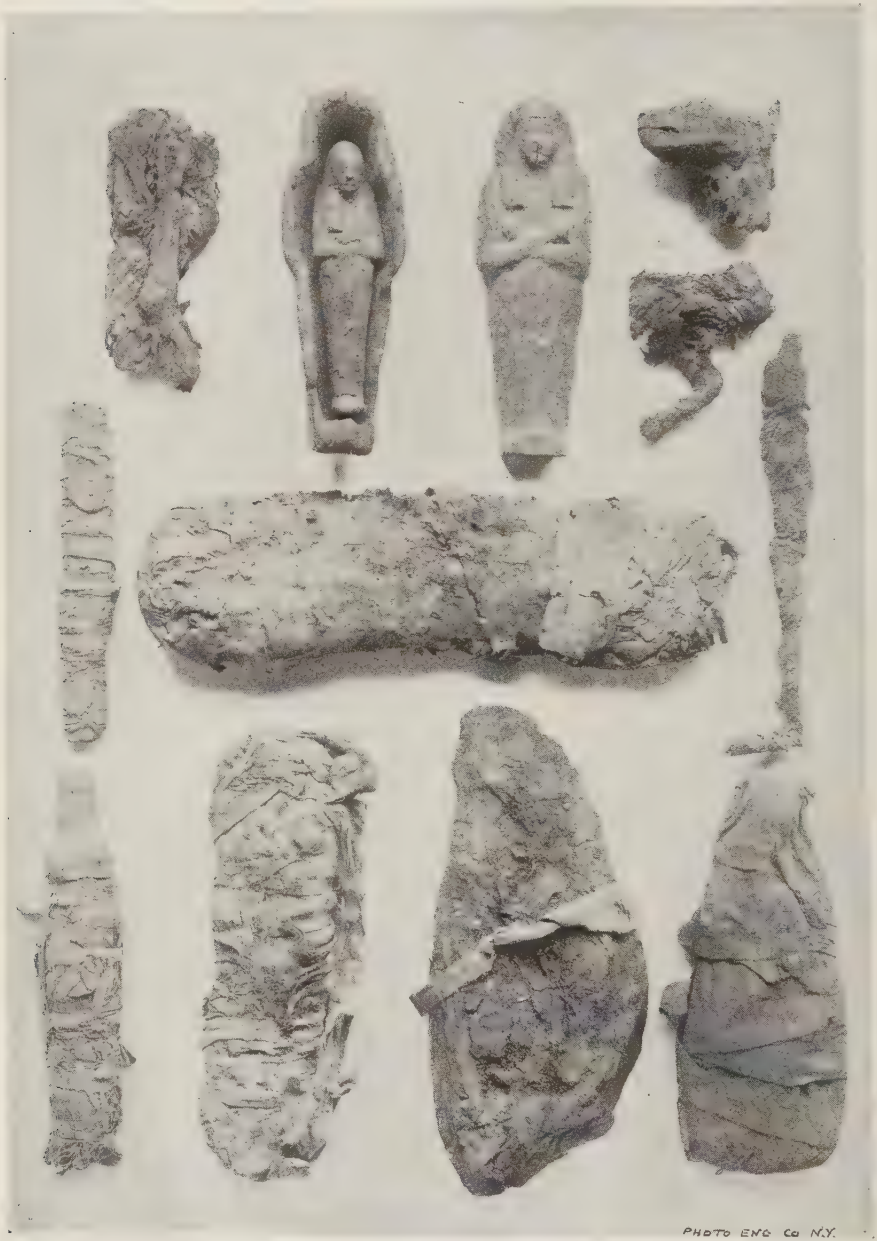
VIEW OF THE HALL FROM THE NORTH SIDE.

VIEW OF THE HALL FROM THE SOUTH SIDE.

EGYPTIAN COFFINS AND SEPULCHRAL BOXES.



MUMMY IN ITS COFFIN.



WOODEN MODEL OF A MUMMY AND FRAGMENTS OF MUMMIED ANIMALS.

THE MOABITE STONE.

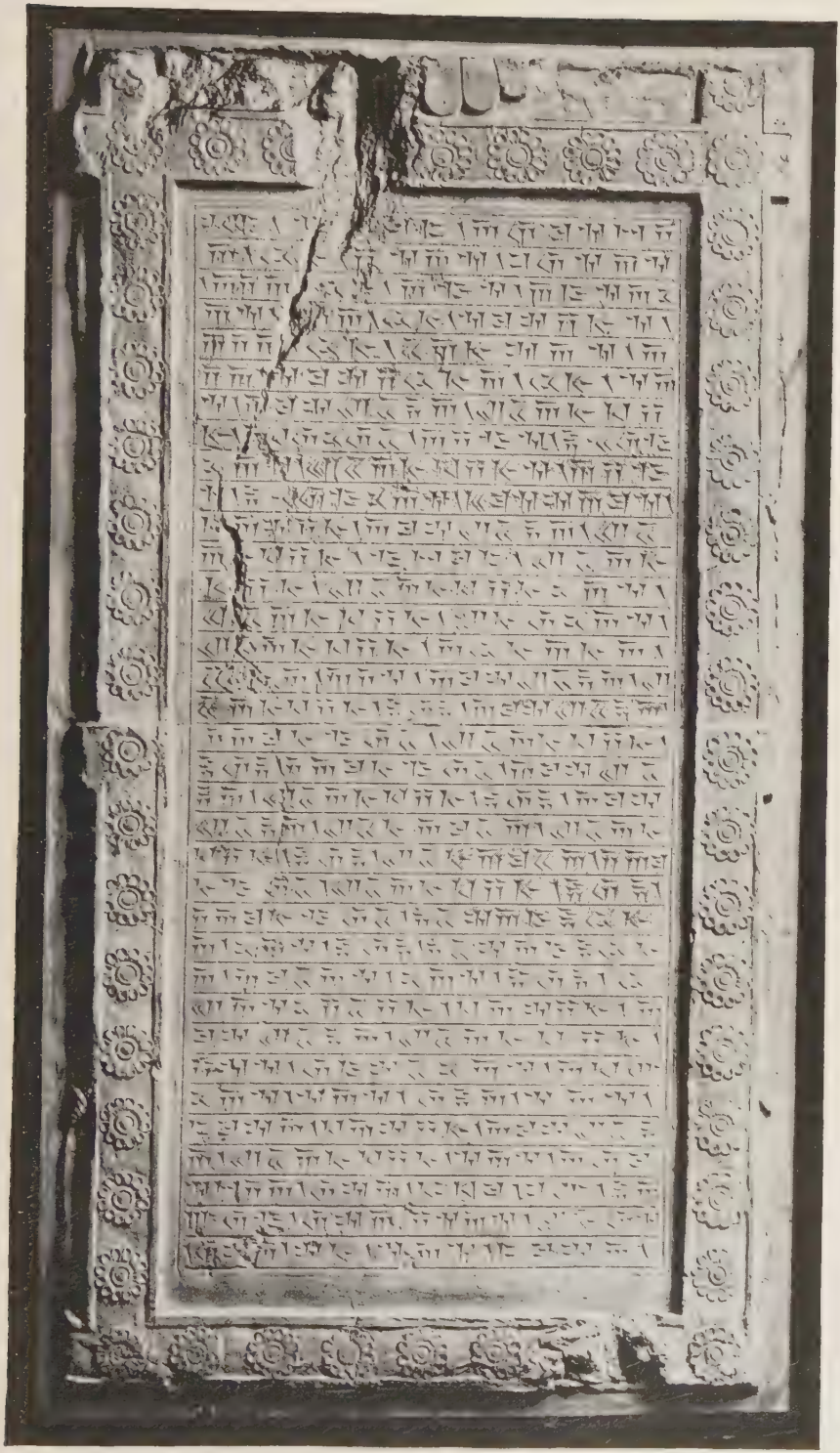
THE BLACK OBELISK OF SHALMANESER.

MOSAIC FROM CARTHAGE: LION ATTACKING A WILD ASS.

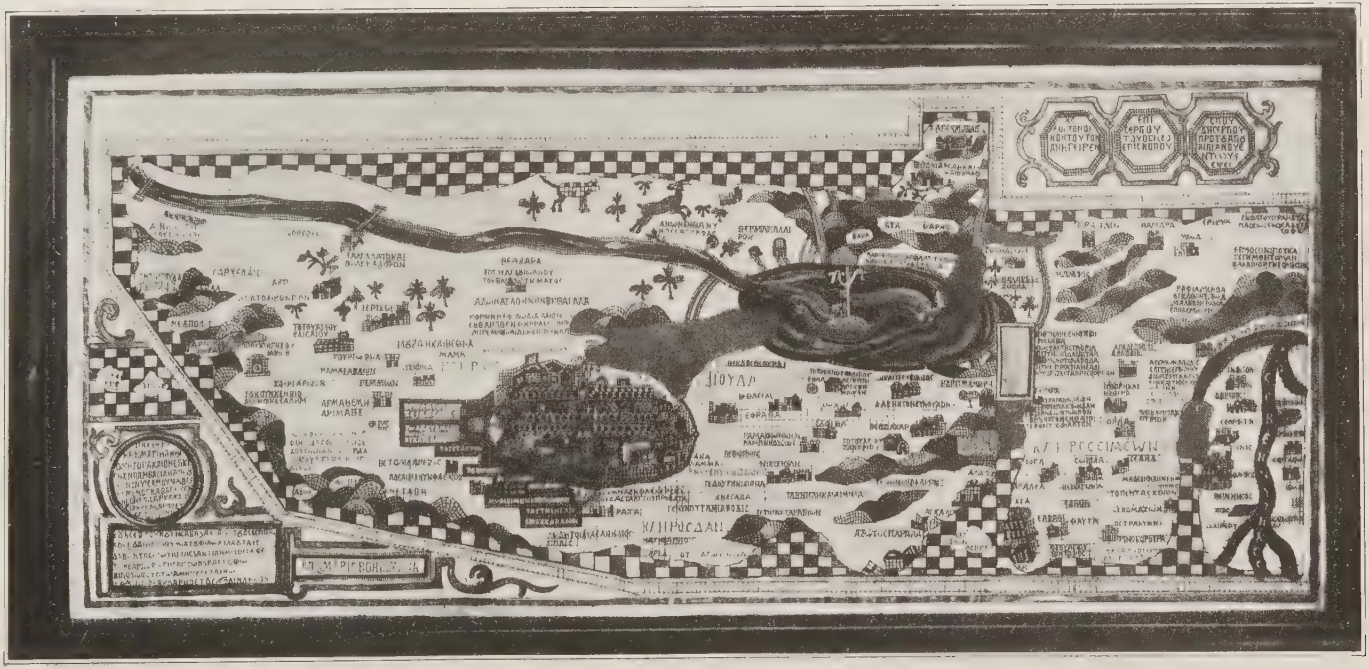
STATUE OF CHEFREN.

STATUE OF QUEEN AMENERDAS.

LID OF THE SARCOPHAGUS OF QUEEN ANKHNEFERABRA.

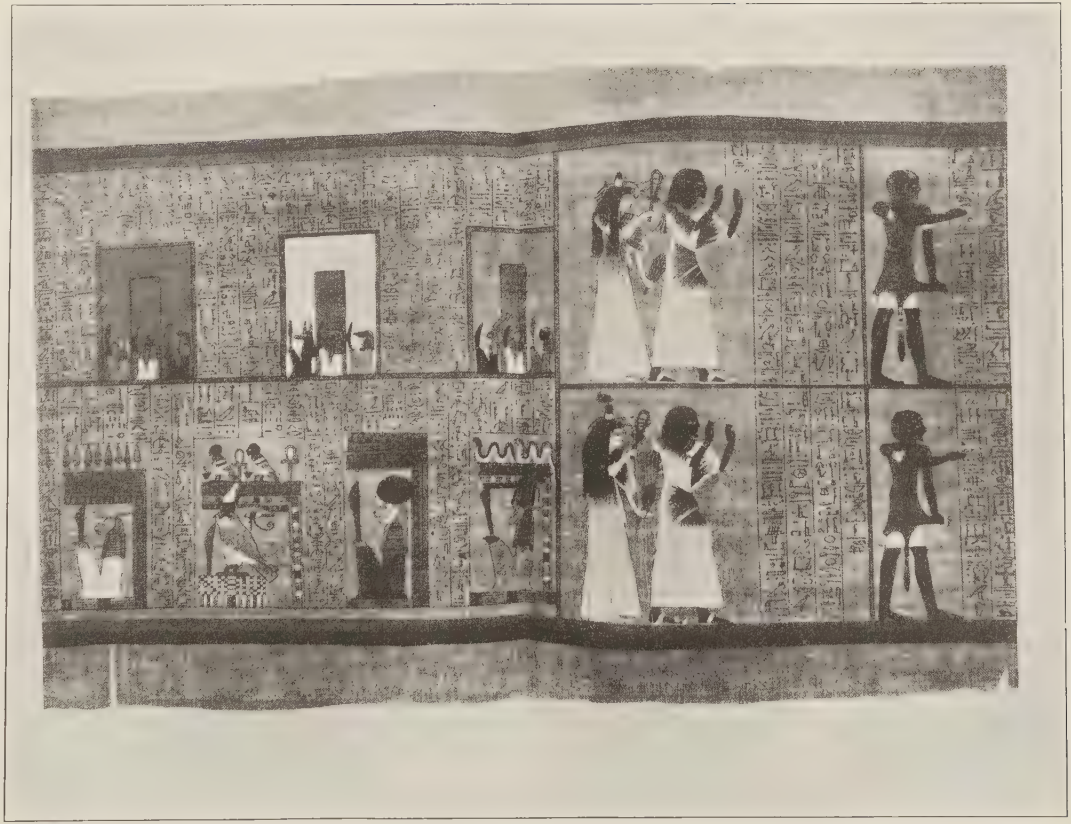


INSCRIPTION FROM PERSEPOLIS.



COLORED DRAWING OF THE MEDEBA MOSAIC MAP OF PALESTINE.

GRECO-EGYPTIAN PORTRAIT.



FACSIMILE OF THE BOOK OF THE DEAD.

shut up Mesha in Kir Hareseth, situated a little to the east of the southern end of the Dead Sea. Mesha, in his emergency, offered his first-born son as a sacrifice, in the presence of the invading army, to Chemosh, the principal divinity of the Moabites, whereupon the Israelites withdrew. Thus far the Biblical account.

In 1868 the Rev. A. F. Klein, a German missionary, discovered at Deban, the ruins of Dibon, the ancient capital of Moab (Numbers xxi, 30; xxxii, 34; Isaiah xv, 2), on the north shore of the river Arnon, a stone or stela of dark blue basalt, 3 feet 8½ inches high, 2 feet 3½ inches wide, and 1 foot 1⅛ inches thick, inscribed with 34 lines, celebrating the achievements of Mesha. The Arabs of the neighborhood, perceiving that the stone was of great value and dreading the loss of such a talisman, broke it into pieces. Fortunately the French archeologist, Clermont-Ganneau, had succeeded in securing a paper impression of the inscription before the stone was broken up. He collected most of the pieces, which, with the aid of his paper impression, were put together and the reconstructed monument is now, together with the impression, in the Museum of the Louvre, Paris, France.

In the inscription Mesha relates that Omri and Ahab, Kings of Israel (I Kings xvi, 21 ff.) oppressed the land of Moab for many years until he recovered several cities from the Israelites, mentioning Medeba (Numbers xxi, 30; Joshua xiii, 9, etc.), Ataroth (Numbers xxxii, 34; Joshua xvi, 2, etc.), and Nebo (Numbers xxxii, 3; Isaiah xv, 2, etc.), where he slew 7,000 people and captured Jahaz, which had been built by the King of Israel, and describes the public works which he undertook and the devastated cities which he rebuilt.

The dialect of the inscription differs only slightly from Hebrew, and the characters employed are those of ancient Hebrew, the so-called Samaritan or Phenician. The Moabite Stone is the most important surviving relic of the Moabite civilization, and its discovery was of great importance for the history of the alphabet (pl. 7).

6. The Black Obelisk of Shalmaneser II, or, as some scholars assume, Shalmaneser III, King of Assyria 860–824 B. C. The original of black basalt, which is now preserved in the British Museum at London, England, was discovered by Sir Austen Henry Layard at Nimrud, ancient Calah (Genesis x, 12), about 19 miles below Nineveh. It is about 7 feet high. The terraced top and the base are covered with cuneiform script containing a record of Shalmaneser's career nearly to the last year of his long reign. The upper part is occupied by five compartments of bas-reliefs running in horizontal bands around the four sides, and representing processions of tribute bearers from five nations. Narrow bands between the compartments contain short legends of the scenes rep-

resented. In 854 B. C. Shalmaneser defeated the confederacy of the Syrian kings, among whom were Benhadad of Damascus and Ahab of Israel, and in 842 B. C., after the siege of Damascus, received the tribute of Jehu, King of Israel (figured and described in the second row). This monument thus supplemented the Biblical narrative, since the participation of Ahab in the Syrian league and the payment of tribute to Shalmaneser by Jehu are not recorded in the Bible. This King is not to be confounded with Shalmaneser IV, 727–722 B. C., who is mentioned in II Kings xviii, 9, in connection with the conquest of Samaria (pl. 8).

7. In the center, on the floor, an ancient Roman mosaic, which formed part of the floor of the temple of Astarte, erected by the Romans at Carthage in the first century B. C., representing a lion attacking a wild ass. The original design, which was very large, is supposed to have been formed of a central mosaic, representing the goddess Astarte driving a chariot drawn by stags, and surmounted by others, depicting a great variety of animals. The fragment measures 6 feet 2 inches by 7 feet 10 inches wide (pl. 9).

8. Statue of Chefren. The original of dark green basalt, which is now in the Museum of Cairo, Egypt, was discovered by Mariette in a temple not far from the great sphinx.

Chefren (Egyptian, Chafra), third king of the fourth dynasty (beginning of the third millennium B. C.), is known as the builder of the second largest pyramid of Gizeh. According to the Egyptian records he reigned 56 years. The King is represented in the conventional attitude of seated figures; the headdress and the throne alone show that the figure represents a Pharaoh. The face is evidently a portrait (pl. 10).

9. Statue of Queen Amenerdas. The original of alabaster is in the Museum of Cairo, Egypt. The statue is of the twenty-fourth dynasty, about 720 B. C., and is the last good specimen of Egyptian art. The face is a portrait. The dress is that of an Egyptian woman. The headdress is the vulture bonnet worn by queens. In one hand is a lash, one of the insignia of royalty, and in the other a sort of purse.

Amenerdas was the sister of So or Sabaco, mentioned in II Kings xvii, 4. While her brother was still alive she was made queen of Egypt. After his death she married an obscure king, Piankhi II.

The inscription of the figure reads: "The beloved of Osiris, the lord of life, the great god; Mut-ha-nefru, the wife of the god (the king); Amenerdas, the daughter of the god (the king)."

The inscription on the pedestal reads: "The princess, Mut-ha-nefru, living forever; the royal daughter, Amenerdas, beloved of Osiris" (pl. 11).

On the walls, on the north side, opposite the Moabite stone: Assyrian four-winged figure holding a chaplet. The figure wears the horned headgear of the Assyro-Babylonian gods and is richly decorated with earrings, necklace, and bracelets. The right arm is lifted up, while the left is stretched out to the front, holding a chaplet or necklace.

Opposite the statue of Chefren: Assyrian bas-relief, representing a winged, eagle-headed genius, holding cone and basket.

On the south side, opposite the statue of Amenerdas: Lid of the sarcophagus of Queen Ankhneferabra. The original, of basalt, is in the British Museum, London, England. Ankhneferabra was high priestess of Amon and wife of Amasis II, King of Egypt about 550 B. C. The sarcophagus is considered as one of the finest monuments of the twenty-sixth dynasty. In the center is the figure of the queen, wearing the headdress of the goddess Isis-Hathor, surrounded by a funeral inscription (pl. 12).

Opposite the Shalmaneser obelisk: Inscription from Persepolis in the Cuneiform characters. The inscription is in the language of ancient Persia. It was engraved at the command of Artaxerxes III, Ochus, who reigned 358–344 B. C., or, according to some, from 359–338 B. C. The following is a translation of the inscription:

A great god is Ahuramazda, who created this earth, who created that heaven, who created mankind, who created prosperity, who made me, Artaxerxes, king, the sole king of multitudes, the sole ruler of multitudes.

Thus speaks Artaxerxes, the great king, the king of kings, the king of countries, the king of this earth:—I am the son of king Artaxerxes, Artaxerxes the son of king Darius, Darius the son of king Artaxerxes, Artaxerxes son of king Xerxes, Xerxes son of king Darius, Darius son of Vishtaspa, Vishtaspa son of one named Arshama, an *Achaemenian.*

Thus speaks the king Artaxerxes: This structure of stone I have built for myself.

Thus speaks the king Artaxerxes: May Ahuramazda and the god Mithra protect me, and this land, and what I have done.

Persepolis was the ancient capital of Persia. It is situated in the interior of Persia proper, forty miles northeast from Shiraz. Persepolis was the name given to this place by the Greeks. Its ancient Persian name is unknown (pl. 13).

10. Screen. On the east side, colored drawing of The Medeba Mosaic Map of Palestine. The original mosaic formed the floor of an old church in Medeba, a town in the former territory of Moab, situated east of Bethlehem, about five miles south by west from Hebron, and often mentioned in the Old Testament (Numbers xxi, 30; Joshua xiii, 9, 16; Isaiah xv, 2; I Chronicles xix, 7). The work dates from the sixth century A. D., and is not only the oldest map of Palestine known, but also the oldest detailed map of any country. Unfortunately, on the occasion of the rebuilding of the church in

1896, when the mosaic was discovered, it was much damaged, but the portion preserved, measuring about 35 feet, includes most of the places connected with Bible history, from Nablus (the Biblical Shechem) in the north to the delta of the Nile in the south. Like all the maps which are based on Greco-Roman tradition, the Medeba map is oriented toward sunrise—that is, when the map is read the east is at the top. It combines a view of ancient Canaan of the Israelites with a picture of Christian Palestine of the Byzantine period. Thus, alongside the Biblical place names are often given those in use at the time of the making of the map, and of the place names, about 140 in number, preserved on the fragment, some 60 have no reference to the Biblical narrative. The map, like the mosaic pictures of sacred history, is an illustration of the Bible narrative rather than a work of geography. The artist was more intent on the picturesque details than on geography. Much care is bestowed on the picture of towns. In the desert, east of the Jordan, a gazelle is pursued by a lion or panther. In the Jordan fishes disport themselves, while its banks are connected by two bridges. On the Dead Sea are shown two vessels, necessarily much out of scale. The inscriptions are in Greek. In addition to the geographical names there are in some cases added Biblical quotations or brief references to historical events (pl. 14).

On the west side: Decree of Canopus. Dr. R. Lepsius, early in 1866, while exploring the Isthmus of Suez and the Delta in the vicinity of the ship canal, uncovered a slab 7½ feet by 2½ feet, the upper part inscribed with hieroglyphics and the lower part with Greek characters. Subsequently a small slab containing a translation of the foregoing into demotic was recovered. The three parts of the stele contain a parallel inscription of 37 lines of heiroglyphics, 73 lines of demotic, and 74 lines of Greek.

The stele was set up at Canopus in the 9th year of Ptolemy III, Euergetes I (247–222 B. C.), to commemorate the great benefits which he had conferred upon Egypt, and particularly his restoration of the images of the gods which the Persians had carried off to Mesopotamia. In grateful acknowledgment of these acts the priests assembled from all parts of Egypt at Canopus, decreed that festivals be celebrated in his honor and in that of his wife, Berenice; that a new order of " Priests of the Beneficent Deities " be constituted, and that a copy of this inscription in hieroglyphics, Greek, and demotic, should be placed in every large temple in Egypt. The decree of Canopus is also called the Tanis Stone (Biblical *Zoan*, Arabic *San*), from the locality in which it was found. The original is in the Museum of Cairo, Egypt.

Below are two Egyptian reliefs, made from squeezes, representing, respectively, men sailing an oar-boat, and four men dragging a sledge.

11. Case containing among other objects a Greco-Egyptian portrait, representing a man's head of the Roman type. One of a collection of the oldest portrait paintings thus far discovered. It was found, along with many others, in the necropolis of Rubaiyat, in the province of Fayum in Egypt. These paintings were executed on thin panels of wood in encaustic (by means of melted white wax mixed with oil and burned in), or distemper (with colors mixed with adhesive substances, as the white and yolk of an egg, gum, size, etc.), or in a combination of the two. They were intended to be portraits of deceased persons, and were placed over the face of mummies, being glued to the linen bandages which enwrapped the body. The custom came up under the Greek domination of Egypt in the third century B. C., and is assumed to have continued till the end of the fourth century A. D. (Pl. 15).

Model of an Egyptian obelisk. Made of brass. The original, a shaft of granite 78 feet 4 inches in height, was erected during the reign of Rameses II, King of Egypt, about 1340–1273 B. C., in front of the temple of Luxor, on the site of ancient Thebes, in Upper Egypt. In 1831, it was transported to Paris, France, where it now stands on the Place de la Concorde. The inscriptions in Latin and French on the pedestal record the erection of the obelisk in Paris, in the presence of King Louis Philippe, in 1836. The original pedestal was left in Egypt.

Book of the Dead. Facsimile of an Egyptian Papyrus at the British Museum, London. The so-called Egyptian "Books of the Dead" are collections of religious texts, hymns, invocations, prayers to the gods, utterances of the gods, etc., intended for the use and protection of the dead in the world beyond the grave. The present collection is that of Ani, "Royal Scribe" and "Scribe of the Sacred Revenue of all the gods of Thebes," who is accompanied on his way through the divers parts of the realms of the dead by his wife Tutu. The hieroglyphic text is accompanied by colored vignettes which depict the various scenes through which the deceased has to pass in the nether world—his appearance before Osiris, the supreme judge of the dead; the weighing of the heart of the departed against the goddess of Truth, etc. (pl. 16).

The Gliddon Mummy Case. This fragment is one third of a mummy case obtained by Mr. George Gliddon at Sakkarah, in Egypt, and presented to the National Institute in Washington, in 1842. At the dissolution of this Society the specimen became the property of the Smithsonian Institution. The remaining two

thirds were divided between the Naval Lyceum of Brooklyn and Mrs. Ward of New York. The mummy case is formed of layers of linen, over which is a thin coating of *chunam* to receive the painting. This *chunam* is a kind of stucco used in Egypt and Hindustan, even to the present day. The figure on the left represents Isis, goddess of dawn, holding in her right hand the *ankh* or *crux ansata*, emblem of life, and in her left hand the *uas*, symbol of power and purity. The figure on the left represents Nepthys, goddess of twilight, with the symbols reversed. The inscription is part of a formula frequent from the 6th dynasty, in the Pyramid of Seti, of Pepi 5th, etc.

Greco-Egyptian papyri, containing accounts of payments of money and in kind; collector's return, fragments of letters, etc., dating from the end of the first century B. C. to the end of the second century A. D.

A selection of Egyptian sepulchral figures. The Egyptians buried with their dead small figures, called *Ushabti* ("answerers,") to serve as substitutes for the deceased and to perform for him whatever agricultural work he might be called upon to do in the realm of the departed, which was conceived as an arable country, where the work of tilling went on as on earth. These ushabti were placed, sometimes in large numbers, either in a special box or upon the floor of the tomb. They were made of wood, clay, terra cotta, stone, glazed faience, and other materials, in form of a mummy with the hands folded upon the breast, and were sometimes laid in the model of a coffin or sarcophagus. In later times they are represented holding a mattock, or hoe, and a reed basket. They are usually inscribed with the name and titles of the deceased, to which is often added a chapter from the Ritual of the Dead.

Scarabs, plaques representing deities, models and molds, etc.

SCARABS.

Scarab or scarabaeus is the name given to the myriads of models of a beetle which are found with mummies, in tombs and ruins of Egypt and other countries which had relations with Egypt. The beetle which was copied in this manner is identified by entomologists with the *Ateuchus sacer*, an insect generally black, occasionally also of blackish green hue, about an inch long by three quarters of an inch broad, found in the southern regions of the Mediterranean. It lays its eggs in a small pellet of dung, rolling it till it assumes the shape of a ball, and then burying it in the sand where the eggs are hatched out by the sun's rays. On account of this habit of the insect the ancient Egyptians saw in it an emblem of the sun god who rolls the sun ball across the sky. It was especially the symbol

of the god Khepera, whose name the scarab bears in Egyptian, the "father of the gods," who created himself and all that exists from emanations of his own body. The scarab, which like the god, was supposed to have produced itself in the mud pellet, became the symbol of resurrection and of perpetual life.

Scarabs were made of every kind of stone known to the Egyptians, also of shell, glass, ivory, faience, or glazed pottery, and even of wood: metal scarabs are rare. In size the scarabs range from a fifth of an inch in length to 4 or even 5 inches, but the commonest size is about three-quarters of an inch by one-half of an inch broad and a quarter of an inch high, and are nearly always pierced longitudinally to receive a thread or thin wire.

By far the greater number of scarabs are carved to represent the beetle standing upon an elliptical base the underside of which is engraved in intaglio with a device or inscription. The engraving depicts figures of gods, men, animals, and flowers, or bears hieroglyphic inscriptions, or ornamental devices, as coils, spirals, rope and scroll patterns. A large number of the inscriptions consist of the names or titles of kings. They were used as seals or signets; were placed with the mummies as expressive of the belief in the revivification of the body and in the renewed life after death, and may also have had an amuletic or talismanic import. Some of them are inscribed with mottoes of good wishes. They are sometimes found strung together and may have been worn as bracelets or necklaces.

The scarab was essentially an Egyptian gem, as the cylinder seal was essentially Assyrian. But the Phenicians borrowed the use of the scarab from Egypt and made it an article of trade. This accounts for the finding of scarabs in various lands bordering on the shores of the Mediterranean.

The Etruscan scarabs, which are frequently found in Tuscany, the ancient Etruria, are generally carved of sard, banded agate, or rock crystal, and are usually engraved with figures or groups derived from the heroic legends of Greece.

12. Case containing the funerary tablet of Nebsumenu, of limestone.

Mummied Ibises. The ibis was the sacred bird of Thoth, the scribe of the gods and the god of learning. Dead ibises were embalmed and buried in earthenware jars. At Memphis there are numerous burial places of the sacred ibises.

An ibis eggshell.

Stone implements. Made of dolorite, granite, limestone, syenite, basalt, and gabbro, in forms of cones, spheroidals, discoidals, etc.

Used as hammers, polishers or rubbers, palettes, etc. Predynastic period.

Rhomboid palette of slate with a depression in the center for holding the ink or paint. Predynastic period.

Predynastic and later pottery.

On the walls on the north side—Assyrian bas-relief representing winged figures kneeling before the sacred tree or tree of life, with an inscription of Ashurnazirpal, King of Assyria 884–860 B. C. On the south side are three Assyrian bas-reliefs, representing, respectively: Head of a priest or divinity;

Wounded Lioness. The original in limestone, which is now in the British Museum, London, was found in 1853 in the ruins of the palace of King Ashurbanipal (668–620 B. C.) at Kuyunjik, the ancient Nineveh. The wounded lioness is regarded as one of the masterpieces of Assyrian sculpture, combining, as it does, simplicity and ease in treatment; and

King with two armor-bearers and a eunuch.

13. Wall case on the west side of the Pavilion, containing Egyptian coffins and casts of the Canopic jars.

In the process of mummification, the viscera were taken out of the body, and after being cleansed and wrapped in linen with spices, salt, etc., were put into four jars, which were placed under the protection of the four gods of the dead, sons of Horus (or Osiris), whose part was to guard them, and therefore also the deceased, from hunger and thirst. Each of the vases was provided with a cover which was made in the shape of a deity, to whom it was dedicated, viz, (1) Emset, human-headed; (2) Hapi, dog-headed; (3) Tuamutef, hawk-headed; and (4) Khebesennuf, jackal-headed. The name, "canopic," was given to these vases by early Egyptologists under the misconception that they represented a certain god whose worship centered in the city of Canopus. The inscription on the vases declares that they belong to "the favorite minstrel of Amon-Re in the fourth class Nes-netret, the justified daughter of the prophet of Amon in Opet-Hot, her mother is Ankhes-en-Aset."

On the wall over the case, Assyrian relief representing Sennacherib receiving the submission of Lachish. The original, of alabaster, which was found in the ruins of Kuyunjik on the site of ancient Nineveh, is now in the British Museum, London. In II Kings xviii, 13 and 14, it is said that Sennacherib, King of Assyria (705–681 B. C.), received tribute from Hezekiah, King of Judah, in the city of Lachish, in southern Palestine. This cast represents the Assyrian King receiving the submission of Lachish. He is seated on his throne, with his attendants holding fly brushes over his head. Behind is a tent, over which is the legend: "Tent of Sennacherib, King

of Assyria." Underneath is seen his chariot with the state umbrella and attendants. Before the King stands an official followed by soldiers, who introduces a file of captives. Overhead is an inscription reading: "Sennacherib, King of the World, King of Assyria, seating himself upon his throne, inspected the booty of Lachish."

Leaving the Pavilion and entering the passage adjoining it, there is on the north side a series of Kensington cases with reliefs between them. From west to east:

14. Collection of Mediterranean pottery (see above, p. 442).

15. Antique iridescent glassware (see above, p. 443). (Pl. 17.)

Persian bas-relief, representing a warrior from Persepolis. (Pl. 18.)

16. Haremhab (or Heruemheb). He was the second successor of Tutankhamen and the last king of the eighteenth dynasty. Cast of the original of granite in the Museum of Cairo, Egypt.

Assyrian bas-relief, representing two warriors with bows and arrows.

17. Antique iridescent glassware.

18. Egyptian antiquities. Collection of necklaces, scarabs, *ushabti* figurines, pendants, potteries, mummy fragments, terra-cotta lamps, coins of Alexander the Great and of the first Ptolemies. The collection was made by the late John Chandler Bancroft Davis when he was United States Minister to Germany, 1873–1877, and presented by the executors of his estate, James Gore King, of New York; Gracie King Richards, of Washington, D. C.; and Bancroft Davis, of Boston, Massachusetts.

Opposite, or south side of the passage, from east to west:

19. Torso of Panammu II. Cast from the dolorite original, found at Senjirli, Asia Minor, and now in the Museum of Berlin. Originally about 9 feet high. On the lower portion is an inscription in relief of 23 lines in the old Aramaean language. Height, 6 feet 2 inches. The inscription says that the statue was erected by Bar-Rekub "before Hadad, El, Rakubel, Shemesh (sun god), and all the other gods of Ja'di" to his father Panammu, son of Bar-Sur, King of Sam'al, a region situated between the Orontes and Taurus in the country of the Hittites; also that, in an uprising against Sam'al, Bar-Sur, grandfather of Bar-Rekub, fell a victim, together with seventy of his house (compare Judges ix, 1–5), Panammu alone surviving. A famine ensued (II Kings vii, 1). With the assistance of Tiglathpileser III, tranquillity was restored, Panammu placed on the throne of his father, and food and drink became plentiful. Panammu followed him on his expeditions, in one of which, before Damascus, he died. His body was carried to his native place, and his son, Bar-Rekub, who set up this stele, was appointed by the

Assyrian King to succeed him. As Tiglathpileser III (Pul, of II Kings xv, 19) occupied the Assyrian throne from 745 to 727 B. C., and was a contemporary of Panammu II and of Bar-Rekub, the maker of the inscription, this monument belongs to the eighth century B. C., and is accordingly one of the earliest in the Aramaean script.

20. Hapi, the Egyptian God of the Nile. Original, of quartzite sandstone, in the British Museum, London. Hapi is in Egyptian the name of the god or personification of the Nile and of the river itself, upon which Egypt was dependent for the issue of its crops. On his outstretched hands the god bears an altar from which hang down bunches of grain, vegetables, flowers, and waterfowl. The statue was dedicated to Amon Re, the supreme god of Egypt, by Shoshenk II, a king of the twenty-second dynasty, about 900 B. C. His grandfather, Shoshenk I, is mentioned in the Bible by the name of Shishak (I Kings xiv, 27; II Chronicles xii, 5, 7, 9). (Pl. 19, fig. 1.)

21. Horus and Altar. Cast of original in the British Museum, London. Horus was worshipped with the other solar divinities of Egypt as the morning sun. As the son of Osiris, the deity of the nether world, he presented the deceased to Osiris. He is generally represented as hawk-headed. His symbol is the winged sun-disk. (Pl. 19, fig. 2.)

22. Assyrian Human-headed Winged Lion. Cast from original, of yellow limestone, preserved in the British Museum, London, England. The original specimen was found by Sir Austen H. Layard in 1846, at Kuyunjik, on the site of ancient Nineveh, and is supposed to belong to the period of Asurnazirpal, who reigned 884–860 B. C. Dimensions, 11 feet by 9 feet.

Figures of composite animals, in stone or metal, sometimes of colossal size, were placed by the Assyrians at the entrances to the temples of the gods and the palaces of the kings. They were considered as emblems of divine power, or genii (Assyrian *shedu*), and were believed to "exclude all evil." Lions were also placed "beside the stays" and on either side of the steps of the gilded ivory throne of Solomon (I Kings x, 19–20). Some Assyriologists connect the Assyrian winged and composite beings with those seen by the Prophet Ezekiel, in his vision of the "chariot" (Ezekiel i), and the cherubim guarding the entrance to Eden (Genesis iii, 24), and those overshadowing the Ark of the Covenant (Exodus xxv, 18, etc.). Compare also the "four living creatures" in Revelation v, 14; vi, 1. Parallels are also found in the sphinx, the chimera, and the griffin. (Pl. 20.)

23. The Babylonian Code of Hammurabi. Cast of an original of black diorite, now in the Museum of the Louvre at Paris, which

was found, in 1901–2, by the French expedition on the site of the ancient city of Susa, the Biblical Shushan, once the capital of Elam and one of the residences of the Persian Kings. On the top of the stele a bas-relief represents the king standing before the sun-god (Shamash), from whom he receives the laws. The code comprises, in the present condition of the monument, 245 distinct laws, and it is assumed that about 35 more have been erased. They are concerned with all the relations of commercial, agricultural, social, and domestic life.

Hammurabi, the originator or compiler of these laws, is identified with Amraphel, mentioned in Genesis xiv as a contemporary of Abraham. This code of laws is thus the oldest in existence, antedating by about one thousand years the Pentateuch, with which it shows many similarities in form and substance (pl. 21).

24. In the alcove, the Rosetta Stone. Cast in plaster from the original, of black basalt, now in the British Museum, London, England. The Rosetta Stone was discovered in 1799 by Boussard, a French officer, near Fort St. Julien, near the Rosetta, mouth of the Nile, in Egypt. The inscription is in the Egyptian and Greek languages. The Egyptian portion is written in hieroglyphic and demotic characters. This bilingular inscription supplied the key to the deciphering of the ancient monuments of Egypt. In its present condition the stone measures 3 feet 3 inches by 2 feet 6 inches, and contains 14 lines of hieroglyphic, 32 of demotic, and 54 of Greek script. The upper part, containing probably 14 or 15 more lines of hieroglyphics and some sculptured ornament on top, has been broken off, and the right-hand bottom corner has also suffered injury. The inscription contains a decree by the Egyptian priests assembled at Memphis, in 196 B. C., to celebrate the first commemoration of the coronation, in the eighth year of his reign, of Ptolemy V. Epiphanes (205–182 B. C.). It enumerates the benefits which the King has conferred upon Egypt, chief among them, that he has reduced taxes; dedicated certain revenues to the temples; released prisoners; abolished the pressgang; and averted great damage from the land by restraining the waters of an unusually high Nile. In return the priesthood directed that a statute of the king, inscribed "Ptolemy the Saviour of Egypt," be set up in the temples; that a shrine containing an image of him be placed in every temple and be carried with those of other deified kings in processions; that the first five days of the month of Thoth should be set apart for special services in his honor; and that a copy of this decree, engraved upon a tablet of hard stone, in hieroglyphics, demotic, and Greek characters, should be erected in each of the temples of the first, second, and third orders (pl. 22).

25. Lid of the Sarcophagus of Sebaksi. Original in the British Museum, London. In Egyptian inscriptions occurs the name Sebaksi as that of an Egyptian priest who lived about 700 B. C. Height, 7 feet 4 inches (pl. 23).

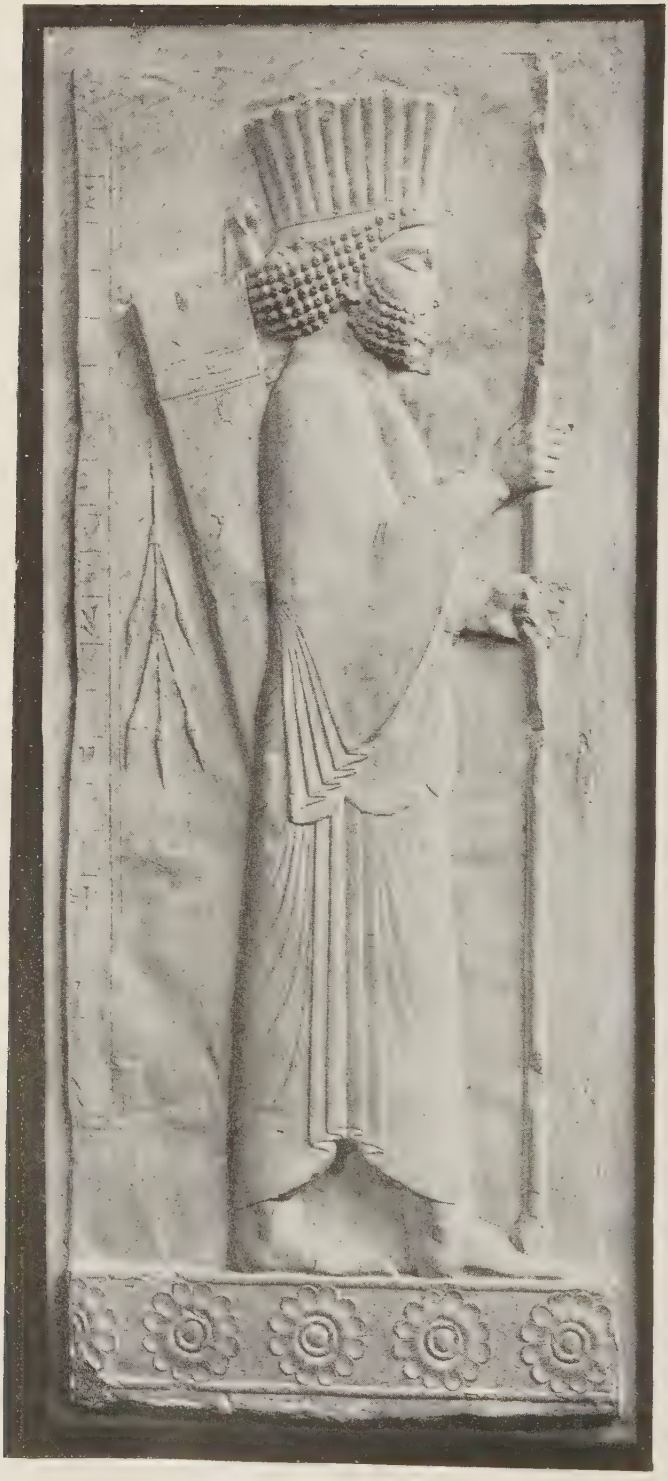
26. Human-headed Winged Bull. The original, of yellow limestone, now in the British Museum, was found by Sir Austen H. Layard in 1846, at Kuyunjik, on the site of ancient Nineveh, and is supposed to belong to the period of Asurnazirpal, who reigned 884–860 B. C. Dimensions, 11 by 9 feet. The winged bulls, like the winged lions, guarded the entrances to the temples and the palaces of the Assyrian monarchs, in order to protect the coming and going of the King. They were called "the bulls of heaven," and were supposed to have been made by Anu, the god of heaven.

27. Stele of Sargon II. Cast from the limestone original in the Museum, Berlin, Germany. It was discovered at Larnaka, in Cyprus, the site of the ancient Kition, by Prof. L. Ross, in 1845. Height, 7 feet; width, 27 inches; thickness, 14 inches. The Stele is a monument of Sargon II, King of Assyria, 722–705 B. C., and of Babylonia, 709–705 B. C. After Sargon had captured Babylonia, Cyprus, called in the inscription *Iatnan*, sent the Assyrian king presents, and in return he gave this image of himself. The inscription is in the archaic Assyrian script, which Sargon adopted after he became king of Babylonia. Sargon was the father of Sennacherib, grandfather of Esarhaddon, and great-grandfather of Ashurbanipal, the Sardanapalus of Greek writers. He captured Samaria, completing the destruction of the kingdom of Israel, which his predecessor, Shalmaneser, had begun. According to the inscriptions, Sargon led 27,280 Israelites into captivity, and transplanted in their country colonists from Babylon, Kutha, Awwa, Hamath, and Sepharvaim (II Kings, xvii, 24). He is mentioned once in the Bible (Isaiah xx, 1), in connection with the campaign against Philistia: "In the year that *Tartan* (commander in chief) came into Ashdod, when Sargon, King of Assyria, sent him, and fought against Ashdod and captured it." That event took place in 711 B. C.

28. Statue of the God Hadad, with inscription in the old Aramaean dialect. Cast from the original of dolorite, found at Gertchin, near Senjirti, northern Syria, and at present in the Museum of Berlin, Germany. Height, 10 feet 5 inches.

This statue was erected by Panammu, son of Karul, king of Ja'di, in northern Syria, in the 8th century B. C., to the gods El, Reshef, Rakubel, Shemesh, and above all to Hadad. Hadad was the name of the Supreme Syrian deity, the Baal, or Sun-god, whose worship extended from Carchemish, the ancient Hittite capital in Syria, to Edom and Palestine. Many Edomite and Syrian kings bore the

ANTIQUE IRIDESCENT GLASSWARE.



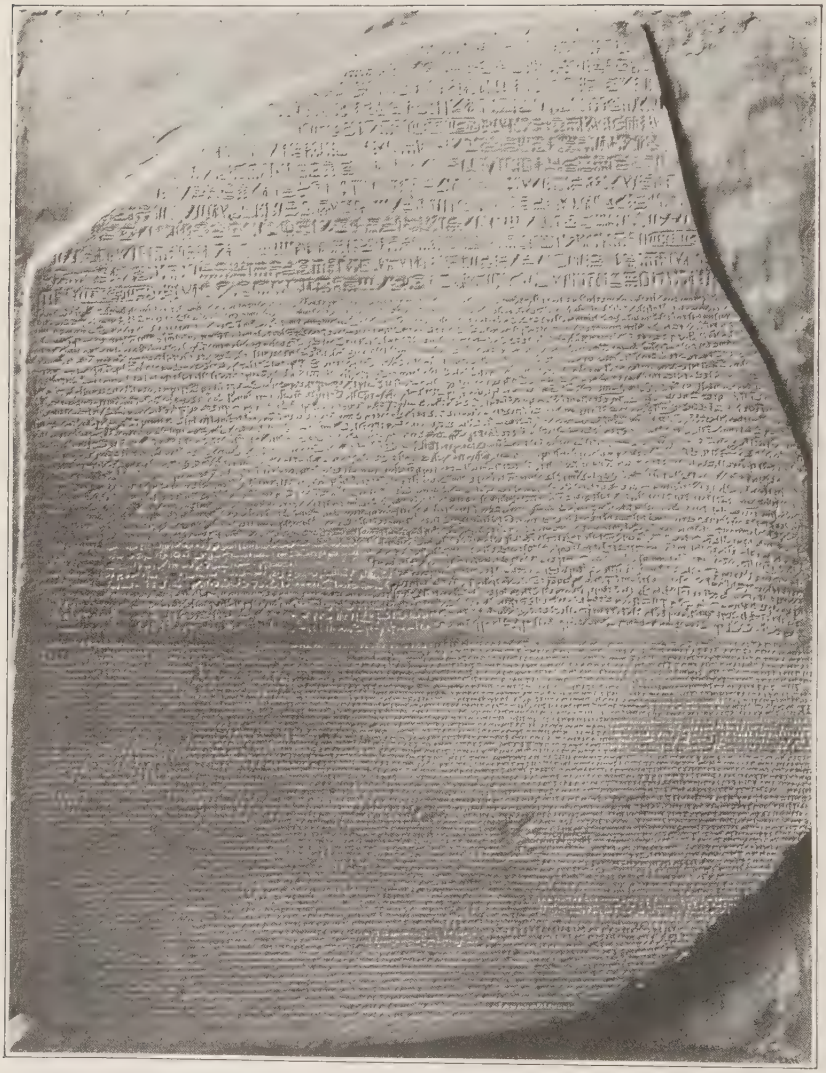
WARRIOR FROM PERSEPOLIS.

1 2

1. HAPI, GOD OF THE NILE. 2. HORUS WITH ALTAR.

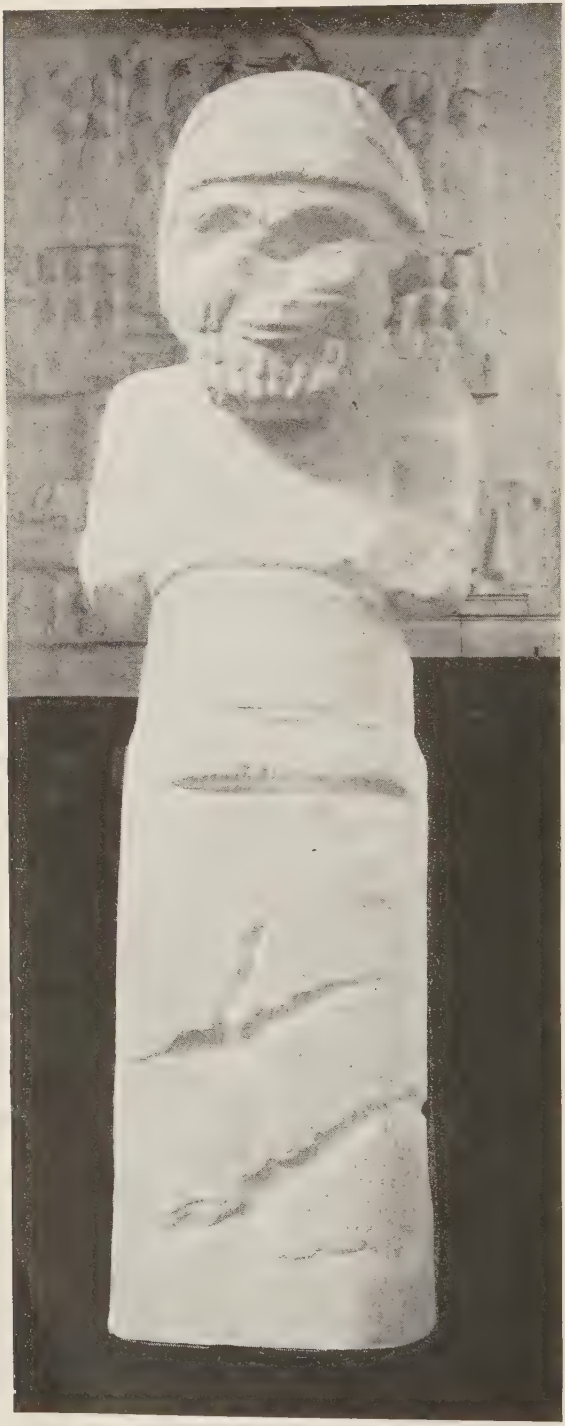
ASSYRIAN HUMAN-HEADED WINGED LION.

CODE OF HAMMURABI.



THE ROSETTA STONE.

LID OF THE SARCOPHAGUS OF SEBAKSI.



STATUE OF THE GOD HADAD.

name of the deity as a title. (Compare Genesis xxxvi, 35; II Samuel viii, 3.) In Zachariah xii, 11, is mentioned a place in the valley of Megiddo named after the two Syrian divinities "Hadad-Rimmon."

The inscription contains 34 lines. The characters are in relief and in form most nearly resemble those of the Moabite stone. The first part (lines 1 to 15) contains the dedication of Panammu to the gods to whom the monument was erected, who conferred on him the government of Ja'di and granted plenty to the land. The second part (lines 15 to 24) relates the injunction of Karul to his son Panammu that he erect a statue to Hadad and honor him with sacrifices. The third part (lines 24 to 34) containes the usual curses against those who would destroy, deface, or carry off the monument (pl. 24).

Above on the wall, west side, Assyrian relief, representing Ashurbanipal, King of Assyria, 668–626 B. C., in chariot hunting lions; on the east side, three Assyrian reliefs, representing, respectively, winged figure holding cone and basket, priest holding a poppy stem in his hand, and a winged, eagle-headed divinity.

In the large western hall there is on the left, or east side, a series of wall cases, while the floor is occupied by two parallel rows of cases. Ranged on bases at the south end of the hall are casts of large sculptures.

Starting from the north side, the first three wall cases (29–31) are occupied by Egyptian antiquities. Above on the wall of the cases are casts of several limestone stelae, representing in succession Rameses II (about 1300–1230 B. C.); the reputed Pharaoh of the Oppression, making an offering to the goddess Hathor; men at various occupations; upper part of the figure of a queen; walking sphinx; two attendants in front of a table; female bust; Amenophis I, King of Egypt, about 1562–1541 B. C.; the priest Hor-em-hat; and perhaps Amenophis IV, about 1375–1358 B. C., who introduced the monotheistic worship of the solar disk and called himself Ikhnaton.

On the upper shelves are *ushabti* figurines and plaster casts of busts.

Underneath, on the wall, are specimens of mummy cloth and of old Egyptian textile art. The latter were found in the tombs of Akhmim, the Greek Panopolis, in upper Egypt, and date from the fourth to the seventh centuries A. D.

On the shelves are parts of coffin lids, representing human heads and faces, of wood, terra cotta and cartonage; funerary cones, fragments of mummied animals, necklaces, rings, scarabs, vases which were found in tombs; an old sun-dried brick and a modern Egyptian brick, which consists of ordinary soil mixed with chopped straw and sun baked. This method of making bricks is alluded to in

Exodus v, 18, where the oppressed Israelites are told, "there shall no straw be given you, yet shall ye deliver the tale of bricks." In the ruins of Pithom, one of the cities where the Israelites were employed, three kinds of brick were discovered, some with stubble, some with straw, and some without. Among the paintings of Thebes, one on a tomb represents brick-making captives with "taskmasters," who, armed with sticks, are receiving the "tale of bricks" and urging on the work. Judging from the monuments, the process of making sun-dried bricks was much the same as in modern times. The clay or mud was mixed with the necessary amount of straw or stubble by treading it down in a shallow pit. The prepared clay was carried in hods upon the shoulders and shaped into bricks of various sizes. There are also some geological and agricultural specimens on the shelf.

On the bottom of the case are a series of busts and statues, viz:

Bust of Amenophis II, King of Egypt about 1450–1425 B. C.

Human-headed Sphinx. With head of a man and body of a lion. Made of limestone and only partly finished. The headdress is that of a royal person, surmounted by a group of symbols consisting of ostrich plumes in front; *uraei* or asps on the side; and the solar disk and horns of Hathor in the rear. On the shoulders are carved in flat relief the sacred beetle or *scarabaeus* and the image of Apis supporting the solar disk. On the breast is the scorpion, the special emblem of the goddess Selk or Serk; and the jackal, emblem of Anubis, the conductor of the dead. Around the legs are wound serpents, and a crocodile appears between the forefeet. Under the belly and supporting the lion is the head of Phthah. Received from the National Institute. Height, 24 inches (pls. 25 and 26).

Royal Head. Of the eighteenth dynasty (about 1550–1350 B. C.). Cast of an original of granite in the British Museum, London, England.

Rameses II, King of Egypt about 1300–1230 B. C. Supposed to have been the Pharaoh of the Oppression. Cast of an original of black granite in the Museum of Turin, Italy.

Statuette of the god Osiris. Egyptian god of the dead. Cast of an original of dark green basalt in the Museum of Cairo, Egypt.

Queen Hatshepset (Hatasu). Daughter of Thothmes I and coregent with her brothers, Thothmes II and Thothmes III of the 18th dynasty (1516–1481 B. C.). Cast of an original of granite in the Museum of Cairo, Egypt.

Statuette of the goddess Isis, wife of Osiris. Cast of an original of dark-green basalt in the Museum of Cairo, Egypt.

Thothmes III, King of Egypt about 1500 B. C. Cast of an original of gray granite in the Museum of Turin, Italy.

Khnumtamon Ramaka, wife of Thothmes III, King of Egypt about 1500 B. C. Cast of an original of limestone in the Museum of Cairo, Egypt.

Statuette of black marble, perhaps representing Antinous, the friend of Hadrian, Roman emperor, 117–138 A. D.

Tirhakah, King of Egypt and Ethiopa, 698–672 B. C. Original of granite in the Museum of Cairo, Egypt. He is referred to in II Kings xix, 9, and Isaiah xxxvii, 9, as attacking Sennacherib, King of Assyria. The inscriptions of the Assyrian king Ashurbanipal (Sardanapalus, Hebrew *Asenappar*, Ezra iv, 10), 668–626 B. C., mention him, under the name *Tarqu*, as king of Egypt and Ethiopia. Manetho, who calls him *Tarkos* (*Tarakos*), says he was the last king of the 25th dynasty. Strabo (xvi, 1, 6) calls him *Tearkon*, and describes him as one of the greatest conquerors of the ancient world.

Head of Amenophis (Amenhotep) IV, King of Egypt about 1375 B. C. Cast. Amenophis IV is known as the "reformer" or "heretic King," because he introduced a sort of monotheism, consisting in the sole worship of the sun god in the form of the solar disk. The original, of limestone, is in the Museum of Berlin, Germany.

Head of the Queen of Amenophis IV. Cast. Original, of limestone, is in the Museum of Berlin, Germany.

Statuette of the Queen of Amenophis IV. Cast. Original, of limestone, in the Museum of Berlin, Germany.

32. In the alcove, plaster model of the Stonehenge. The Stonehenge is a megalithic monument standing on Salisbury Plain, Wiltshire, England. Few of the huge stones now remain in their original position. From the portions of the structure still extant it is assumed to have been composed about as follows: In the center was a large slab—the altar stone—15 feet long. Around this, 19 monolithic pillars, over 20 feet in average height, were set in a horseshoe or ellipse. The open part of the horseshoe faces the sunrise at the summer solstice. Surrounding this, and concentric with it, was another horseshoe composed of 5 triliths, formed each of 10 monolithic pillars with their capstones. Outside this ellipse was a circle of 30 or 40 smaller pillars. This was inclosed within another circle of about 100 feet in diameter, formed by 30 great monolithic pillars capped with large lintel stones. Outside of this circle, again, was a circular earthwork, or rampart, inclosing an area about 300 feet in diameter.

Excavations undertaken on the site of the monument brought to light, together with some coins and pottery fragments, nearly 100 stone implements of various kinds which had been employed in dressing the rude blocks into regular shape.

Some consider the structure a temple dedicated to the worship of the sun, and assign its erection to the end of the Neolithic period on the ground that no bronze relics were found. Analogous stone circles, of which about 200 are known in the British Isles, were chiefly used as tombs, and this would suggest that sepulture was at least one of the purposes for which Stonehenge was erected. This would also account for its situation on Salisbury Plain, where there existed in the Bronze Age an extensive necropolis, as evidenced by the numerous barrows in the vicinity of the Stonehenge. This would by no means exclude its use as a temple. It may have served for the performance of funerary rites analogous to the mortuary temples of Egypt.

33. The fourth wall case contains Babylonian and Assyrian antiquities:

On the wall of the case are casts of Assyrian bas-reliefs, representing warriors with a bull; a king slaying a lion, and a flute player in front of a palm tree.

On the upper shelf are bisque statuettes of Sennacherib, King of Assyria 705–681 B. C., and of Ashurbanipal, King of Assyria 680–668 B. C., and his queen; a sacrificial dish which is adorned on the four corners with the heads of bulls, an animal which was much venerated by the Assyro-Babylonians, and engraved on the sides with various figures and symbols; head of a priest, and an amphora of alabaster.

On the lower shelf are incantation bowls inscribed in the Aramaic language found in Babylonia; iridescent glass bottles, glazed tiles; besides:

The Chaldean Deluge Tablet, containing the cuneiform text of the Babylonian account of the Deluge, as restored by Professor Paul Haupt. Engraved in clay under the direction of Professor Haupt, by Dr. R. Zehnpfund, of Rosslau, Germany. The Babylonian story of the Deluge is contained in the eleventh tablet of the so-called Izdubar or Gilgamesh legends, commonly known under the name of the Babylonian Nimrod Epic. The Babylonian narrative of the Deluge closely accords, both in matter and in language, with the Biblical account as contained in Genesis vi–viii. Xisuthrus or Hasisadra or Zit Napishtim, the hero of the Babylonian account, corresponding to the Biblical Noah, is informed by a god of the coming flood and ordered to build a ship to preserve himself, his family and friends, and various animals. After sending out divers birds (a dove, a swallow, and raven) he lands on the mountain Nizir in Armenia and offers a sacrifice to the gods, after which he is taken to live with the gods.

The originals were found during the British excavations in the valley of the Euphrates and Tigris, and are now preserved in the British Museum in London (pl. 27).

Babylonian Votive Tablet of the Sun-god. Cast from the original of alabaster, now in the British Museum, London. Found in 1881 in the ruins of Abu Habba, the site of ancient Sippara, which is identified with the Biblical Sepharvaim, one of the centers of the worship of the sun god, Shamash. The sun god is seated on a throne in his shrine, holding in his right hand a staff and a circle, the emblems of his authority. Above are the symbols of the sun god, the moon god, and of Ishtar (Aashtarte). Before the shrine is an altar, with the sun disk on it held with ropes by two attendants. Three persons approach the god in adoration. Over them is an inscription reading: "Image of the sun-god, the great lord, who dwells in the temple Ebabbara (white house) in Sippar." The inscription below and on the other side of the tablet recounts the history of the temple (pl. 28).

A selection of seals. The cast of a bronze bell, now in the Berlin Museum, merits notice because of the design running around the cup, representing demons portrayed as wild animals of hybrid character in an upright posture and in a threatening attitude.

On the bottom of the case: Babylonian boundary stone. Boundary stones record grants of land to individuals by royal decree, or transfer of property made by legal procedure. They are decorated with the god or gods (in the present instance, the sun god Shamash) who are invoked as witnesses to the transaction, and were set up at the boundary of the property in question as memorials of the gift or transfer.

Torsos of the figures representing Gudea, an ancient priest-king (*patesi*) as architect. The originals of black diorite, now in the Museum of the Louvre in Paris, France, were found in an ancient temple at Telloh, Babylonia, during the extensive excavations undertaken in 1877–1881 by M. Ernest de Sarzec, the French vice consul at Bassora.

Gudea ("Speaker" or "Prophet," in Semitic, Nebo) reigned about 2500 B. C. The figure is seated on a stool in a religious attitude. The hands are clasped in the oriental posture of meditation and devotion. On the knees is held a tablet with plan of a fortress having six gates flanked by towers and walls surrounded by battlements. In front of this tablet there is a graduated rule 10§ inches long (=27 cm., i. e., a Babylonian half cubit), and at the side is the stylus with which the architect engraved his design. The figure is clad in a sleeveless cloak crossed over the breast and thrown back over the shoulder. The inscription covering the figure is known as

"Inscription F of Gudea." The writing is in the early hieroglyphic forms of the cuneiform script, and it runs not from left to right in horizontal lines as in the later Assyro-Babylonian inscriptions, but from above downward, beginning at the right and thence proceeding toward the left in parallel vertical columns, the face of the characters being turned toward the right, not the left, as in Chinese. The same arrangement is met with in the Egyptian hieroglyphics.

Two Babylonian inscribed bricks.

Assyrian Bas-reliefs. Plaster cast reductions, representing: First row, human-headed winged lion and bull, and between them Gilgamesh, who is identified with the Biblical Nimrod, holding a lion; second row, religious procession; third row, King Sargon (722–705 B. C.) and suit; fourth row, heads of a king and of a eunuch, with an offering scene in the center.

Babylonian Altar with Bas-reliefs. Cast of an original circular altar of diorite, now in the Museum of the Louvre, Paris, which was discovered by M. de Sarzec in the ruins of Talloh, on the site of the ancient city of Sirpula, South Babylonia.

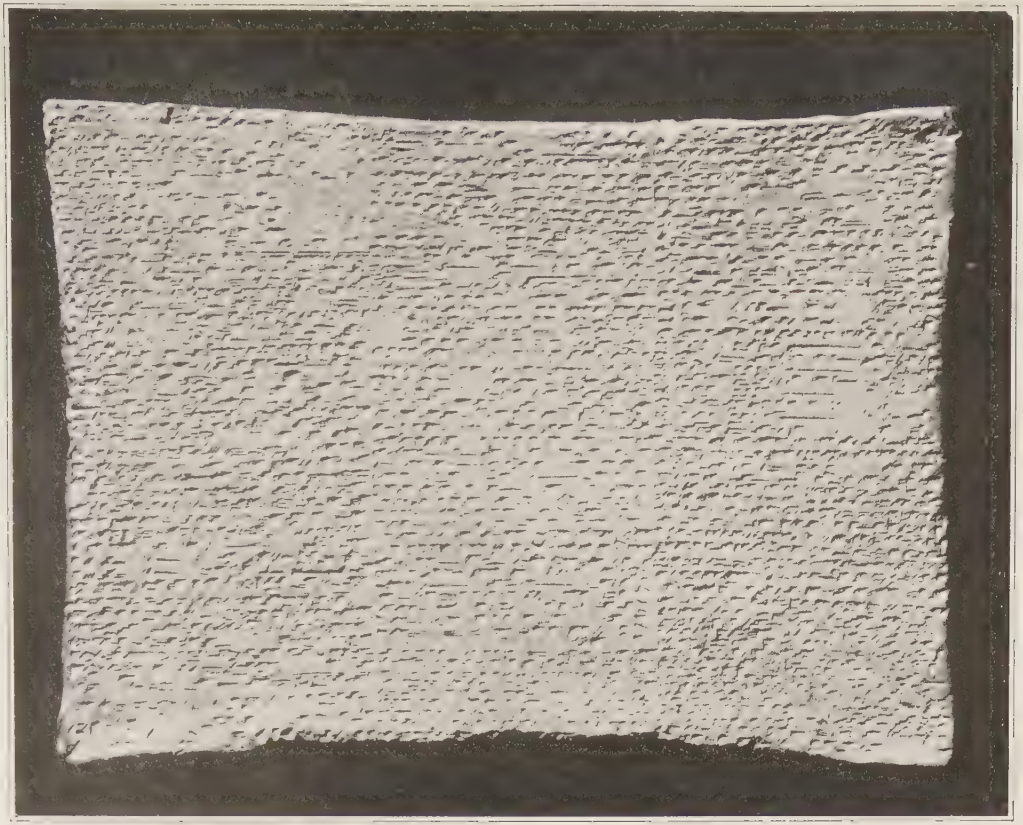
34. The next wall case is given over to Biblical antiquities. The fashion of dress and ornament, as well as the form of household utensils, is, it may be assumed, in the "unchanging East" essentially the same at the day as in Bible time, and the collection shown of objects of modern life and industry in the Orient explain or illustrate many allusions in the Scriptures. On the wall, Syrian coat, called in Syriac *abba*, consisting of red cloth embroidered in white, and worn as an outer garment.

Sling (Hebrew, *Kel'a*) from Damascus, Syria. The sling as a weapon of war is first mentioned in Judges xx, 16. David killed Goliath with a stone thrown from a sling (I Samuel xvii, 40). The Israelitish army was provided with companies of slingers (II Kings iii, 25). The sling was also employed in the wars of the Romans against the Jews (Josephus, Wars of the Jews iii, 7, 18; iv, 1, 3). According to the monuments the sling was both an Egyptian and an Assyrian weapon. It consisted of a strip of leather or woven material, wide in the middle to receive the missile, and narrowing at both ends into a rope. Not only were smooth stones used for hurling, but also balls made of burnt clay, of lead, and various other hard substances. The sling is still used by shepherds to drive away wild animals from their herds, as in the time of David (I Samuel xvii, 40). (Pl. 29.)

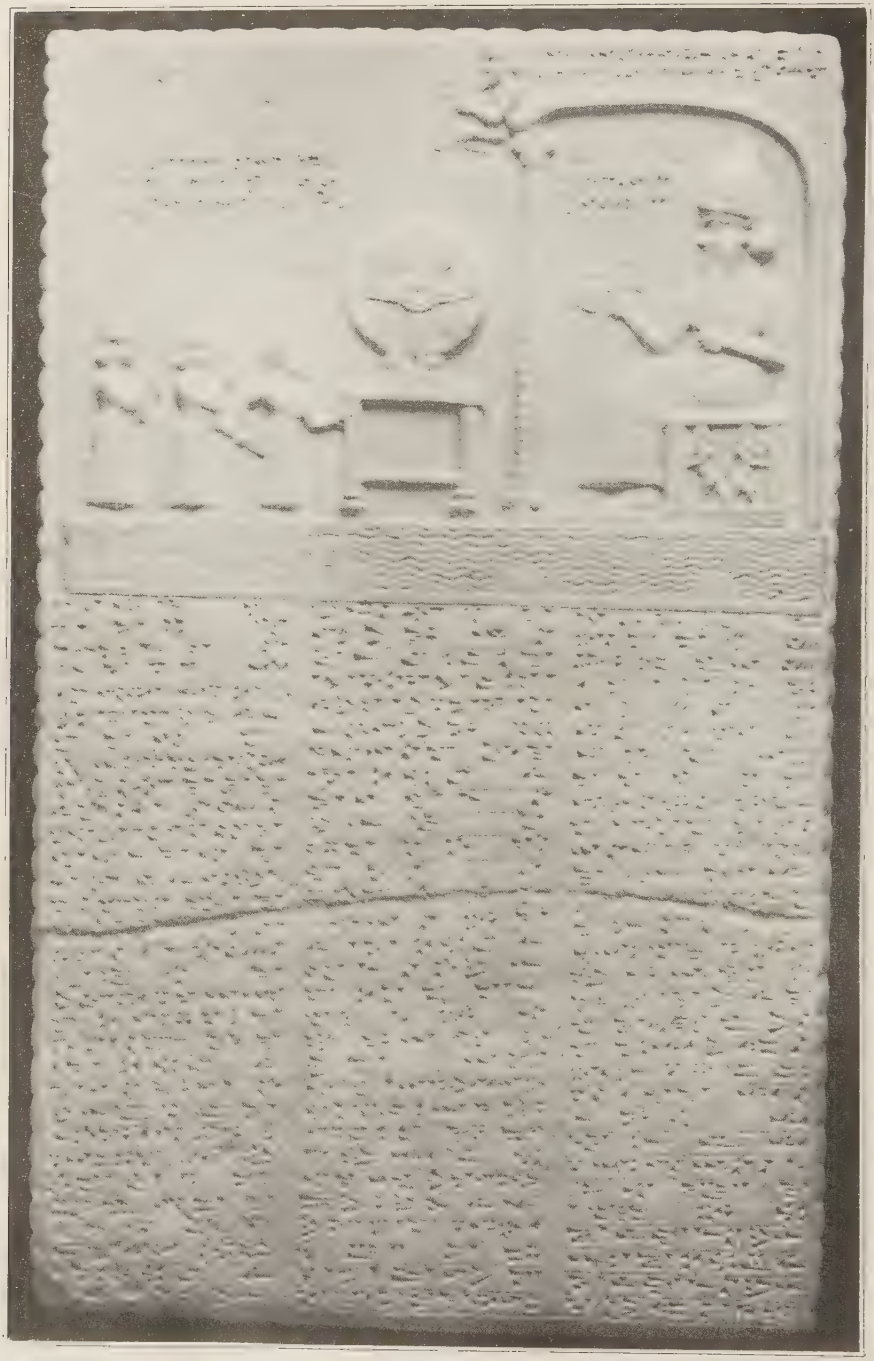
Bird trap (Hebrew, *pah*) from Baghdad, Mesopotamia. The usual method of catching birds was with the trap, which consisted of two parts: a net strained over a frame, and a stick or spring (Hebrew, *mokesh*) to support it, but so placed that it should give

HUMAN-HEADED SPHINX, FRONT VIEW.

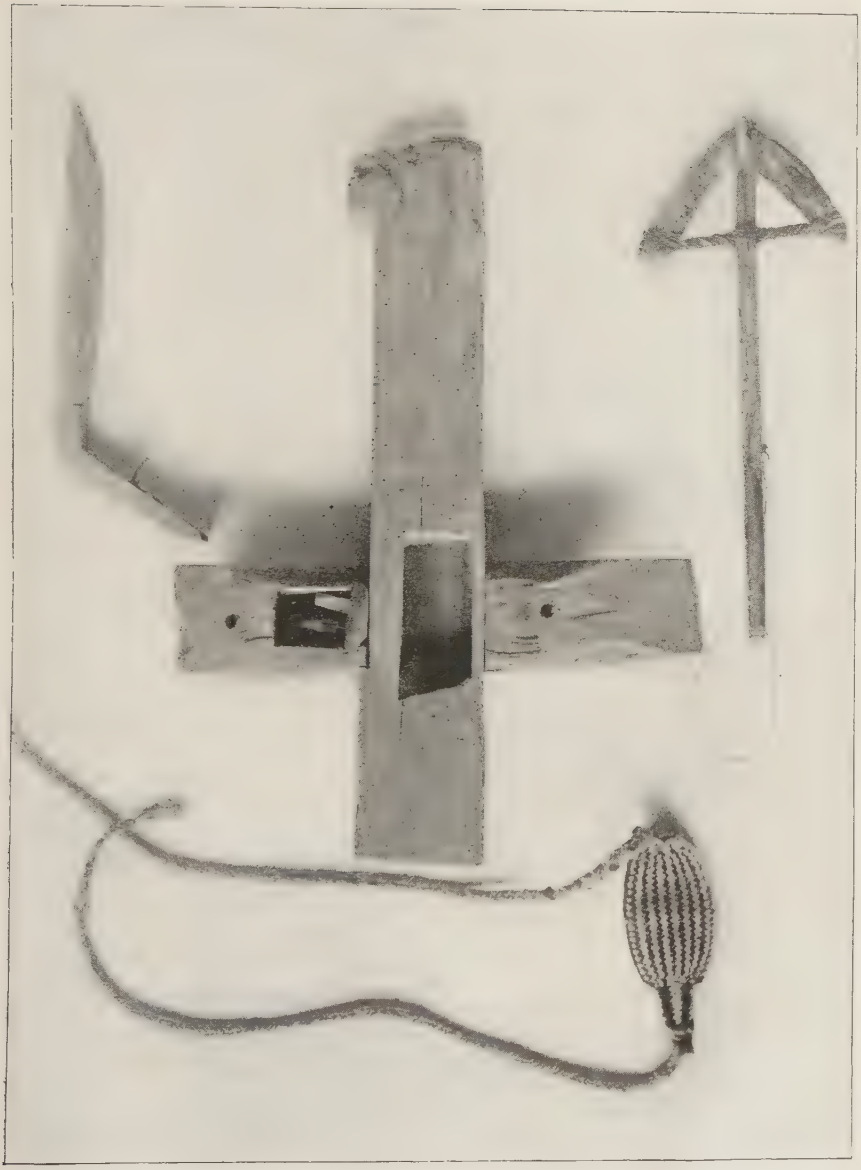
HUMAN-HEADED SPHINX, SIDE VIEW.



THE CHALDEAN DELUGE TABLET.

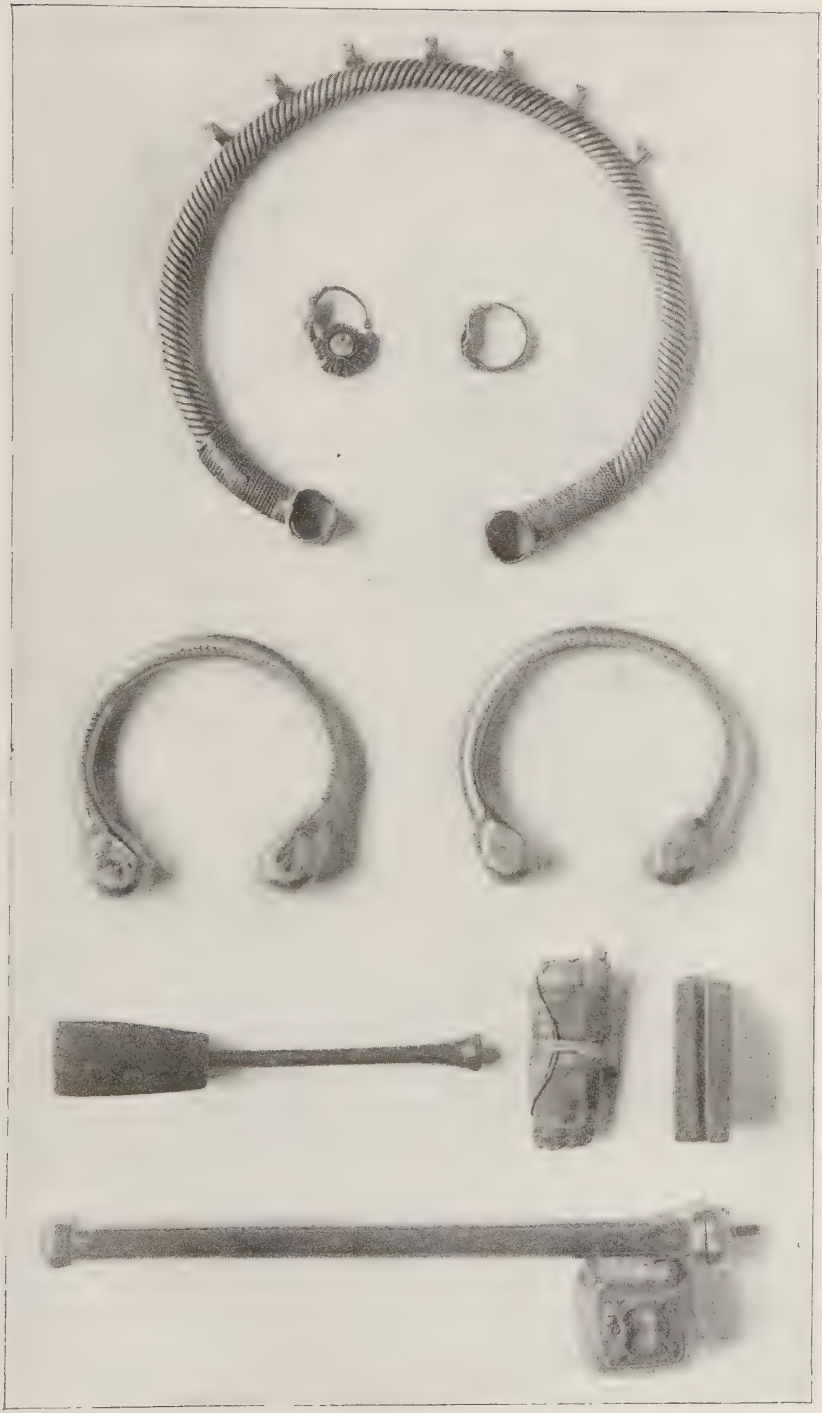


BABYLONIAN VOTIVE TABLET OF THE SUN-GOD.

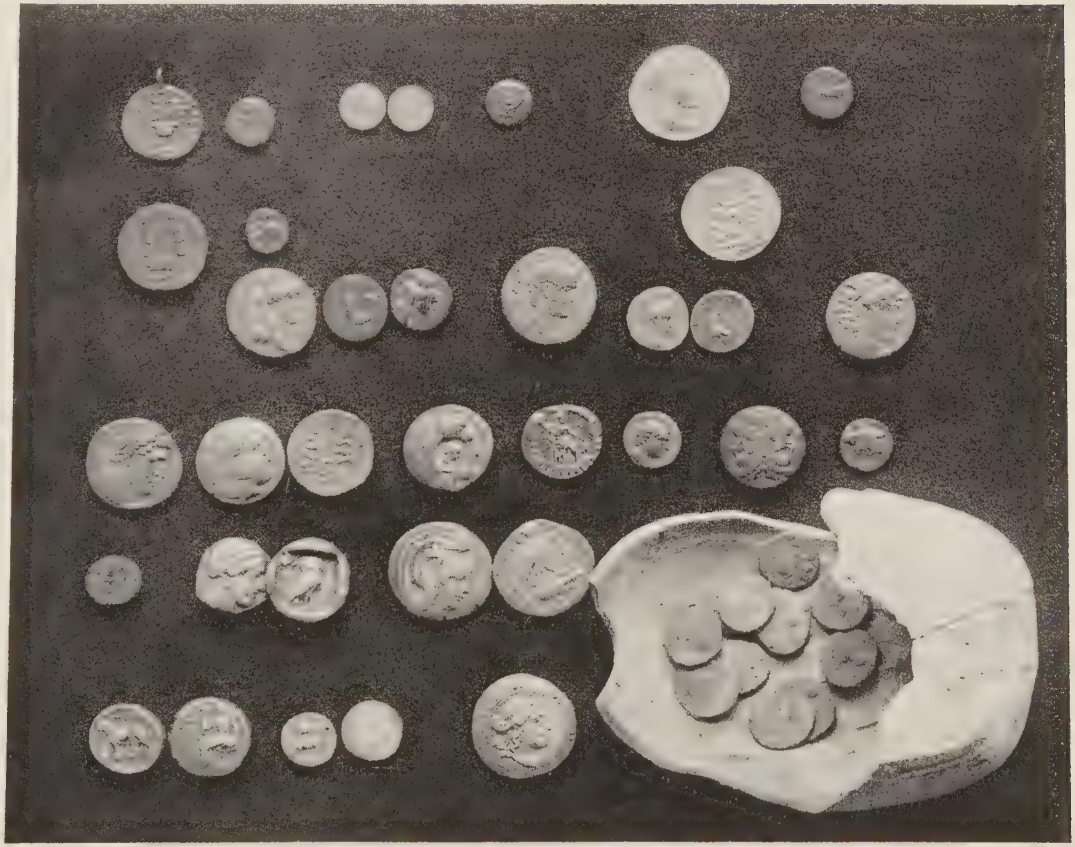


SLING, BIRD TRAP, DOOR LOCK AND KEY.

SHEEPSKIN COAT.



1, NECKLACE; 2, NOSE RING AND WEDDING RING; 3, ANKLETS; 4, KOHL WITH IMPLEMENTS FOR APPLYING IT TO THE EYES; AND 5, INKHORN.



COINS OF BIBLE LANDS.

way to the slightest touch. The bird trap is frequently compared with the ensnaring of the heedless and the weak (Amos iii, 5; Psalms cxxiv, 7; Proverbs vii, 23; Job xviii, 9; Ecclesiastes ix, 12). (Pl. 29.)

Sheepskin coat from Syria. Skins of animals were the primitive material used for clothing (Genesis iii, 21), and were not wholly disused at later periods. The "mantle" of the prophet Elijah (I Kings xix, 13, 19; II Kings ii, 13) was probably the skin of a sheep or some animal with the hair left on, wherefore he is called the "hairy man" (II Kings i, 8). This dress was characteristic of the office of prophet: "Beware of false prophets, which come to you in sheep's clothing, but inwardly are ravening wolves" (Matthew vii, 15; Zechariah xiii, 4). Pelisses of sheepskin still form an ordinary article of dress in the East (pl. 30).

On the middle shelf, geological and agricultural specimens and a selection of the insects of Palestine.

On the lower shelf, a collection of the precious stones of the Bible. There are three almost identical lists of precious stones in the Bible:

I. The description of the High Priest's "breastplate of judgment" (*hoshen ha-mishpat*), in which were placed, in gold setting, four rows of precious stones, three in each row, engraved with the names of the twelve tribes of Israel, Exodus, xxviii, 17–20:

[The Hebrew names are given in *italics*. The English names are of the Revised Version; those in parenthesis occur in the margin of the Revised Version.]

1. Sardius (Ruby), *odem*.
2. Topaz, *pitdah*.
3. Carbuncle (Emerald), *bareqeth*.
4. Emerald (Carbuncle), *nofek*.
5. Sapphire, *sappir*.
6. Diamond (Sardonyx), *yahalom*.
7. Jacinth (Amber), *leshem*.
8. Agate, *shebo*.
9. Amethyst, *ahlamah*.
10. Beryl (Chalcedony), *tarshish*.
11. Onyx (Beryl), *shoham*.
12. Jasper, *yashpeh*.

II. The description of the ornaments of the King of Tyre, Ezekiel, xxviii, 13:

1. Sardius (Ruby).
2. Topaz.
3. Diamond (Sardonyx).
4. Beryl.
5. Onyx.
6. Jasper.
7. Sapphire.
8. Emerald (Carbuncle).
9. Carbuncle (Emerald).

III. The description of the foundation of The Heavenly City, Revelation, xxi, 19, 20:

1. Jasper.
2. Sapphire (Lapis-Lazuli).
3. Chalcedony.
4. Emerald.
5. Sardonyx.
6. Sardius.
7. Chrysolite.
8. Beryl.
9. Topaz.
10. Chrysoprase.
11. Jacinth (Sapphire).
12. Amethyst.

Besides the stones enumerated in these lists there are probably mentioned the diamond by the Hebrew name of *shamir*, Jerem. xvii, 1; Ezek. iii, 9; Zach. vii, 12; amber (margin of Revised Version, electrum), Hebrew *hashmal*, Ezek. i. 4; and crystal, Hebrew *qerah* and *gabish*, properly ice, according to the view of the ancients that crystal was ice hardened by intense cold, Ezek. i, 22; Job xxviii, 18; Revel. iv, 6.—In many cases it is very uncertain whether the English rendering of the Hebrew names designates the same precious stones as the nomenclature of modern mineralogy.

The engraving of signets upon hard stones was practiced at an early period. The Israelites may have acquired the art from the Egyptians, who are known to have made use of the lapidary's wheel and emery powder, and are supposed to have been acquainted with the diamond and the method of engraving other stones by means of it. The Assyrians and Babylonians were very skillful in engraving on gems, many of which have been found in the ruins of their palaces and cities.

Silver necklace (Hebrew, *'anaq*,) Baghdad, Mesopotamia. The custom of wearing a necklace is alluded to in Proverbs i, 9; Canticles i, 10; iv, 9. It consisted either of a single band or chain, or of a series of ornaments, as pearls, pieces of corals, or diamonds strung together. Animals ridden by kings were decorated with collars of precious materials (Judges viii, 26). (Pl. 31, fig. 1.)

Gold nose ring (Hebrew, *nezem*), Baghdad, Mesopotamia. The Hebrew word *nezem* denotes both earring and nose ring. The latter is meant in Genesis xxiv, 47; Isaiah iii, 21; and Proverbs xi, 32: "As a jewel of gold in a swine's snout, so is a fair woman which is without discretion." In modern times the rings are often of extraordinary size and frequently reach to the mouth, so that they must be removed in eating (pl. 31, fig 2).

Silver anklets (Hebrew, *'akasim*), Baghdad, Mesopotamia. Anklets, as ornaments worn by women, are mentioned in Isaiah iii, 16, 18. From these passages it would seem that the tinkling produced by knocking the anklets against each other was their chief attraction (pl. 31, fig. 3).

Kohl (Hebrew, *puk*) and the implements of its use for painting of the eyes. Baghdad, Mesopotamia. The practice of applying pigments to the eyelids and eyebrows, in order to enhance the brilliancy of the eyes was common in the East in Bible times (Jeremiah iv, 30; compare Proverbs vi, 25), and is still in everyday practice. The pigment, which is a preparation of antimony, is applied to the eyelids by means of a small blunt piece of wood, ivory, or metal, which is moistened, dipped in the mixture, and then drawn carefully along the edges of the eye. From the Arabic name "Kohl"

comes the term "alchohol," the fineness of the powder suggesting the idea of highly rectified spirits (pl. 31, fig. 4).

Lachish Tablet (the original of clay is in Constantinople). This tablet was discovered in 1892, by Dr. F. J. Bliss, in the ruins of Tell el Hesy, on the site of the ancient Lachish, which was one of the capitals of the Canaanites, situated southeast of Jerusalem, between Gaza and Eleutheropolis, conquered by Joshua (compare Joshua x, 3, 31, and 32). It was also besieged and taken by the Assyrian king, Sennacherib, during his invasion of Judah (II Kings xviii and xix; Isaiah xxxvi and xxxvii), in 701 B. C., and later succumbed to Nebuchadnezzar. The tablet, which dates before the conquest of Palestine by the Israelites, contains, in cuneiform script and in a Semitic dialect akin to the Aramaic, a letter from the chief of the territory adjoining Lachish, probably to the governor of Lachish, complaining that marauders from the neighboring region are besetting Atim, which is probably identical with Etam, of the south of Judah, mentioned in I Chronicles, iv, 32, and Samhi or Sam'a, now probably represented by the large ruin of Sami'ah, situated 5 miles to the south of Etam.

Hebrew seals. The use of seals or signet rings is already mentioned in the Patriarchal epoch, Genesis xxxviii, 18. The seal was either hung on a string around the neck, or worn in rings on the finger (compare Jeremiah xxii, 24). The seal was used for signing letters and documents, and also for sealing purses, doors, and the like (compare I Kings xxi, 8; Job xiv, 17; Matthew xxvii, 66). The custom of making an impression with the seal upon the forehead of a person is alluded to in the Epistle to the Galatians vi, 17; Revelation vii, 3.

Seal of Haggai, Son of Shebaniah. (Cast of the original of black stone). Jerusalem. Found by Sir Charles Warren in 1867 near the Haram esh-Sherif, the mosque of Omar (on the site of the temple). The names Haggai and Shebaniah may be connected with the rebuilding of the Temple.

Ancient Hebrew Weight. (Cast from the original of hematite.) Samaria. Found by Dr. Th. Chaplin. Weighs about 4 grains. Inscribed "quarter of a quarter of *netzeg*," which may have been a standard weight in Palestine.

Wright bead. (Cast from original of reddish yellow stone.) Jerusalem. Obtained by Prof. T. F. Wright. Inscribed *netzeg*, which may denote standard weight.

Syrian inkhorn (Hebrew, *geseth ha-sofer*), made of brass. Palestine. The inkhorn is mentioned in Ezekiel ix, 2, as being carried "by the side," that is, fastened to the girdle of the scribe. It

is still carried in this fashion in the Orient. The inkhorn consists of a tube containing reed pens and a receptacle for ink. (Pl. 31, fig. 5.)

A selection of Coins of Bible Lands. Coined money, which originated about 700 B. C. in Lydia, did not circulate among the Israelites previous to their return from the Babylonian captivity. The money mentioned in the Bible before this date consisted of precious metals, mostly silver, in the form of bars, ingots (properly "tongue," Joshua vii, 21), disks (*Kikkar*), or rings (often represented on Egyptian monuments) which may have had a fixed valuation and weight. Generally the metal was weighed on scales to determine its value. Thus the name of the piece of money most frequently occurring in the Bible, the *Shekel*, properly denotes "weight."

The first coins mentioned in the Bible after the exile are the *Adarkon* and *Darkemon* (Ezra viii, 27; Nehemiah vii, 72), which are identified with the Persian gold Daric. Upon the overthrow of the Persian monarchy, Greek coins of the denominations of talents and drachms began to circulate in Palestine. The earliest Jewish coins are shekels and half shekels of silver, and one-sixth of shekel of bronze, struck by Simon Maccabaeus, 143 B. C. (I Maccab. xv, 6). Some attribute the first coinage of the shekel to Ezra. The succeeding Maccabaean or Hasmonaean princes down to 37 B. C. struck small bronze coins with Hebrew or Hebrew and Greek inscriptions. The Idumaean or Herodian princes coined bronze money bearing their names in Greek characters. At the same time the Roman procurators of Judaea (since 6 B. C.) also struck bronze coins with Greek inscriptions. The last coins struck by the Jews were those during the revolt under Bar-Cochba (132 A. D.). Greek and Roman money was current in Palestine in addition to the native Hebrew coins, as seen from the New Testament. The selection includes the following coins.

Shekel. Silver. Attributed to Simon Maccabaeus. Obverse, Pot of Manna (Exod. xvi, 33), with legend: "Shekel of Israel, year two:" reverse, Budding rod of Aaron (Numb. xvii, 8), legend: "Holy Jerusalem."

Coin of John Hyrcanus (136–106 B. C.). Original of copper. Obverse, "Jochanan, High Priest and Prince of the Jewish Confederation"; reverse, Two cornucopias and a poppy head.

Widow's Mite. Coin of Alexander Jannaeus (105–78 B. C.). Copper (facsimile). Obverse, "Jonathan the High Priest and the Confederation of the Jews" within a wreath of olive; reverse, Two cornucopias and a poppy head. It is assumed that this or a similar

coin is referred to by the term "widow's mite" in Mark xii, 42; Luke xii, 6, though in the original it is denominated *lepton*, as none but Jewish coins were permitted within the Temple precincts.

Coin of Herod Antipas. Bronze. Obverse, "Herod, Tetrarch," with a palm branch; reverse, Tiberias within a wreath. Herod Antipas, Tetrarch of Galilee and Petrea, A. D. 4–39, is often mentioned in the New Testament (Matt. xiv, 1–3; Luke iii, 1, 19, etc.). It was he who beheaded John the Baptist (Matt. xiv, 1), and to him was Christ sent for examination by Pilate (Luke xxiii, 7). In honor of the Emperor Tiberius he founded the city of Tiberias on the western shore of the Sea of Gennesareth, where the coin was struck.

Coin of Herod Philip II (died A. D. 34). Struck at Caesarea Philippi in honor of the Eighth Roman Legion. Copper. (Obverse "Herod Philip," with his portrait; reverse, the standards of the Legion. Herod Philip is mentioned once in Luke iii, 1, as Tetrarch of Ituraea: Caesarea Philippi was often visited by Christ (Matt. xvi, 13; Mark viii, 27). It is now a small village called Banijas, near Mount Hermon.

Coin of Agrippa II (last Jewish king). Bronze. Obverse, Name and head of the Emperor; reverse, "Money of Agrippa, struck at Neronias" (=Caesarea Philippi). Herod Agrippa II, the last Jewish prince of the house of Herod, is mentioned (Acts xxv, 13, and xxvi, 2, 28) as having an interview with the Apostle Paul.

Denarius, or Roman Tribute Penny. Silver. Obverse, "Tiberius Caesar, son of deified Augustus"; reverse, "Pontifex Maximus" (Chief Priest). Value about 16 cents. The denarius was the tribute money that the Jews had to pay to the Romans, and it is very likely that a variety of this coin was shown Christ with the question: "Is it lawful to give tribute to Caesar or not?" (Matt. xxii, 17.)

Stater. Antioch. Silver (facsimile). Obverse, "(Money) of Caesar Augustus," with a head of the Emperor; reverse: Tyche (Fortune), as genius of the city of Antioch, with her foot on the river god Orontes, and the words: "Thirtieth year of the victory" (i. e., Actium). The stater, about equal in value to the shekel, is mentioned in Matt. xvii, 27, as having been found by Peter in the mouth of the fish, sufficient to pay the Temple tribute, which was half a shekel (Exod. xxx, 13, 15), for Christ and himself.

Coin of Caesarea. Bronze. Obverse, Head of Augustus Caesar. Caesarea, founded by Herod I, is frequently mentioned in the Acts. It was the scene of the conversion of the centurion Cornelius (x); Philip preached the Gospel here (xxi, 8); Paul was imprisoned here two years before he was sent to Rome (xxiv–xxvi); here also Herod Agrippa I died, 44 B. C. (xii, 19). It was the

residence of the Roman Governors, and here the Jewish war against Rome broke out.

Tetradrachm of Sidon. Silver. Obverse, Head of the city; reverse, "(Money of the Sidonians) Holy and inviolable," with the figure of Astarte. Sidon, the oldest city of Phenicia, is often mentioned in the Bible (Joshua, xix, 28; I Kings v, 6; Acts xxvii, 3). It is at present represented by the town of Saida, with about 15,000 inhabitants.

Tetradrachm of Tyre. Silver. Obverse, Head of Hercules as Baal (Lord) of the city. Tyre, next to Sidon, the oldest and most important city of Phenicia, is often referred to in the Bible. During the period of David and Solomon friendly relations were entertained between Tyre and Israel (I Kings v, 15 ff.). The coast of Tyre was visited by Christ (Matt. xv, 21; Mark vii, 24), and Paul landed at Tyre on one of his missionary voyages (Acts xxi, 3). The modern Çur is an unimportant town with about 5,000 inhabitants.

Coin of Ashkelon. Bronze. Struck by order of Emperor Alexander Severus, about A. D. 228. Ascalon, or Ashkelon, was one of the five chief cities of the Philistines, situated 30 miles southwest of Jerusalem (Joshua xiii, 3; I Samuel vi, 17). It was the center of the worship of Derceto, the supposed female counterpart of Dagon (Jud. xvi, 23; I Sam. v). It is now represented by the village of Askalan.

Coins of the City of Damascus. Copper. Damascus, the ancient capital of Syria, is mentioned as early as in the history of Abraham (Genesis xiv, 15; xv, 2). Later it frequently came in contact with Israel (II Sam. viii, 6; II Kings xvi, 9 f., etc.). In the New Testament it is especially known from the history of the Apostle Paul (Acts ix; xxii, 6).

Tetradrachm of the City of Babylon. Silver. Struck by Mazaios, Governor under Alexander the Great, 331–328 B. C.

Tetradrachm of Alexander the Great (336–323 B. C.). Obverse, head of Alexander; reverse, Zeus seated holding the eagle. Alexander the Great is mentioned in I Maccabees vi, 2. It is also assumed that he is typified under the emblem of the "he-goat" in Daniel viii, 5, and that his empire is meant by the "fourth monarchy" depicted in Daniel ii, 40 and vii, 23 f.

Tetradrachm of Seleucus I Nicator, King of Syria, 312–280 B. C. Silver. Obverse, Head of Seleucus; reverse, "King Seleucus," with figure of Jupiter. The city of Seleucia, the principal port of Antioch, from which Paul and Barnabas set out for Cyprus (Acts xiii, 4), was named after Seleucus I.

Coin of Antiochus III, the great, King of Syria, 223–183 B. C. Silver. Obverse, Head of the King; reverse, "King Antiochus,"

with the figure of Apollo seated on tripod. Antiochus is mentioned in I Macc. viii, 6 ff.; Josephus, Antiquities xii, 3.

Tetradrachm of Antiochus VII Sidetes, or Euergetes, King of Syria, 138–127 B. C. Silver. Obverse, Head of the King; reverse, "(Money) of King Antiochus Euergetes," with the figure of Minerva holding Victory. Antiochus Sidetes is mentioned, I Macc. xvi, 1 ff., as being defeated by the sons of the High Priest Simeon.

Coin of Demetrius Soter, King of Syria 162–150 B. C. Obverse, head of Demetrius; reverse, "King Demetrius Soter," with seated female figure. He waged war against the Maccabees and is often mentioned in the books of the Maccabees (I Maccabees viii, 31; x, 2, etc.).

Tetradrachm of Ephesus. Silver. Struck 140 B. C. Ephesus, in ancient time one of the most important cities in Asia Minor, was especially celebrated for its temple of Diana (Acts xix, 35). It was the place of residence of Paul (Acts xix, 1 ff.), of Timothy (I Timothy i, 3), and of the Apostle John, who probably died there. Ephesus was one of the seven churches referred to in the Revelations (Revelations ii, 4). It was also the seat of the third general Council (431 A. D.), and of the "Robber Synod" (449 A. D.).

Tetradrachms of Tarsus. Silver. Struck by Satrap Datames, 250 B. C. Tarsus, the ancient capital of Cilicia, Asia Minor, was the home of Apostle Paul (Acts ix, 11, 30; xi, 25; xxii, 3). It is still a city of about 10,000 inhabitants. It is now accessible from Alexandretta by rail.

Coin of Cyprus. Bronze. Struck under Emperor Claudius (A. D. 41–54), and the Proconsul Sergius Paulus. Cyprus, one of the largest islands in the Mediterranean, was the birthplace of Barnabbas (Acts iv, 36), and often visited by Paul, while Sergius was its proconsul (Acts xiii, 4 ff., etc.). In the Old Testament it is referred to by the name of Kittim (Gen. x, 4; Numb. xxiv, 24; Dan. xi, 30, etc.).

Hemidrachms of Ephesus. Silver. Struck 200 B. C. Obverse, Bee; reverse, Deer.

Aes (farthing) of Thessalonica. Copper. Struck 88 B. C. Obverse, Head of Janus; reverse, Dioscuri. Thessalonica, formerly the capital of Macedonia, is the modern Salonica. Two Epistles of Paul are addressed to the Christians of this place.

Coin of Thessalonica. Copper. Struck 158 B. C. Obverse, Head of City Nymph; reverse, Galley.

Tetradrachm of Macedonia. Silver. Struck between 156 and 146 B. C. Obverse, Head of Minerva upon a Macedonian shield; reverse, Club of Hercules. Macedonia is often mentioned in the New Testament. Paul visited this province on his second and

third missionary voyage and founded congregations in several of its cities (Acts xvi and xx).

Didrachms of Athens. Silver. (470 to 230 B. C.). Obverse, Head of Athene (Minerva); reverse, Owl. Athens, the former capital of Attica and the modern capital of Greece, was visited by Paul, where he delivered the discourse on the Areopagus (Acts xvii, 15 ff.).

Tetradrachms of Athens. Silver. (470 to 230 B. C.). Obverse, Head of Athene (Minerva); reverse, Owl (the bird sacred to Athene) (pl. 32).

On the bottom of the case: Goatskin water bag (Hebrew, *nod*, *hemeth*). Palestine. Skin bottles are referred to in Genesis xxi, 14; Joshua ix, 5. Christ employs them in a comparison, "Neither do men put new wine into old wine skins" (Matthew ix, 17). Such bottles are made from the whole skins of animals, generally the goat. After the animal is killed and its feet and head removed, the rest of the body is drawn out entire without opening the belly, and after the skin has been tanned, the places where the legs were cut off are sewed up; when the skin is filled it is tied about the neck Skin bottles are also in use in Spain, in the City of Mexico, and by the Eskimos (pl. 33, fig. 3).

SYRIAN MORTAR AND PESTLE. SYRIA.

The mortar is of white marble, 8 inches high by 12 inches square; the pestle is of wood, 14 inches long. The mortar is at present used in Syria, particularly in the preparation of a dish called *Koebe*, consisting of meat and wheat, which, after having been crushed in the mortar, is rolled out, cut in diamond forms, which, sandwiched with layers of meat, are baked in a pan. In ancient times the mortar was used for crushing grain in general. Many stone mortars have been found in the excavations of Gezer, a city often mentioned in the Old Testament (Joshua x, 33; xvi, 10, etc.).

MILLSTONES (HEBREW, REHAYIM). BAGHDAD, MESOPOTAMIA.

Millstones are often referred to in the Bible, and they are still used in grinding corn, in the same form as in ancient times. They consist of two cylindrical stones; the lower one is firmly planted on the ground and provided with a convex upper surface on which the concave under surface of the other stone revolves. The upper stone, which is called *rekeb* or rider, has a hole through its center into which the grain is dropped, and through which runs a shaft to hold the stone in place. A handle attached to the "rider" enables a person sitting near to turn it around and grind the grain, which is fed with

the hand that is free. It was forbidden to take the mill or even the upper stone in pledge, as taking "the life" (that is, the means of sustaining life), Deuteronomy xxiv, 6. Each day as much grain as was needed was ground, and the "voice of the mill" became proverbial (Jeremiah xxv, 10; Ecclesiastes xii, 4). At the time of Christ, mills turned by asses were also employed (Matthew xviii, 6, Revised Version, margin). At present water mills are also largely used in Syria (pl. 33, figs. 1, 2, and pl. 34).

WOODEN DOOR LOCK AND KEY. BAGHDAD, MESOPOTAMIA.

The doors of Eastern houses, which are usually small and low, seem early to have been provided with hinges turning in sockets and with locks and keys in whose construction no little ingenuity was displayed (Judges iii, 23, 25; Proverbs xxvi, 14; Canticles v, 5; Nehemiah iii, 3). It is likely that locks and keys were made both of iron and of wood, according to circumstances. A wooden key, now quite generally in use, is described as consisting of a piece of wood about a foot in length, provided at one end with a series of pegs. It is thrust into a little opening at the side of the door and applied to the bolt. This has a corresponding series of holes into which the pegs of the key fit, displacing thereby another set of pegs, by which the bolt is held in its place (pl. 29). Pair of Shepherd's Shoes. Made of goat skin. Syria.

35 and 36. The next two cases contain a collection of Bibles and musical instruments of the Bible. The Museum's collection of some sixty-five Bibles includes manuscripts and old editions of the original text, as well as copies of the most important ancient and modern translations of the scriptures.

EDITIONS OF THE ORIGINAL TEXT OF THE BIBLE.

Hebrew Bible. Facsimile of the Aleppo Codex. The original manuscript, which is assigned to Aaron ben Asher (beginning of the tenth century A. D.), but is probably of somewhat later origin, is preserved in the Synagogue of Aleppo, Syria. (Pl. 35.)

Hebrew Bible without vowel points. Printed by Christopher Plantin in Antwerp, 1573–'74.

Hebrew Bible. Edited by Elias Hutter in 3 volumes. Hamburg, 1587. Hutter was Professor of Hebrew in Leipzig. The peculiarity of this Bible consists in the fact that the roots are printed in solid black letters, while the prefixes, suffixes, and formative letters (called servile letters in Hebrew grammar) are in outline.

Rabbinic Bible. Edited by Joannes Buxtorf, printed by Ludwig Koenig in Basel, Switzerland, 1618–'19. The Bible contains the

Old Testament in two folio volumes. The Hebrew text is surrounded by the Massora, the Targum, and the commentaries of Rashi, Ibn Ezra, Kimchi, and others.

Greek New Testament. First American edition. Printed by Isaiah Thomas, Worcester, Massachusetts, 1800. (Pl. 36.)

Greek New Testament. Second American edition. Printed by S. F. Bradford, Philadelphia, 1806.

ANCIENT VERSIONS OF THE BIBLE.

The oldest and most important version of the Old Testament, which in turn became the parent of many other translations, is the Greek of Alexandria, Egypt, known by the name of the Septuagint. The name Septuagint is derived from the tradition that it was made by a company of seventy (sometimes seventy-two) Jewish scholars, at Alexandria, under the reign of Ptolemy Philadelphus, 285–247 B. C., who desired a copy for the library he was gathering. The truth of its origin seems to be that Alexandria became, after the Babylonian captivity, a center of the Jewish population. As time went on, the Jews lost command of the Hebrew language and required a translation of their sacred books into Greek. The men who met this want differed very much in knowledge and skill, were of an indeterminate number and of different periods, beginning the work at the time of Ptolemy Philadelphus and ending it about 150 B. C. The Pantateuch is much more carefully translated than the rest of the Bible. Books now considered apocryphal were included in the Canon. The Septuagint was used by the Jews until the second century of the Christian era, when they reverted to the Hebrew. It was also, no doubt, used by the Apostles and by the Church Fathers, who refer to it under the name "Vulgata."

Codex Vaticanus. Containing the Old and New Testament. Facsimile. Six volumes. Rome, 1868–1881. The Codex Vaticanus, so called from the fact that it is preserved in the Vatican at Rome, is the best and oldest Biblical manuscript now known. It is written in Greek in uncial characters (capitals), and was probably the work of two or three scribes in Egypt during the fourth century. The original is probably the most valuable treasure of the Vatican library. It was brought to Rome by Pope Nicholas V in 1448. The manuscript is not quite complete; there are a few gaps in the Old Testament, and the New Testament ends with Hebrews ix, 14.

Codex Sinaiticus. Facsimile edition, Petrograd, 4 volumes. 1862. The Codex Sinaiticus was discovered in 1859 by Constantine Tischendorf in the Convent of St. Catharine at the foot of Mount Sinai. It was transferred to Cairo, then to Leipzig, and later to Petrograd, where it is preserved in the Imperial Library. This

text was printed at Leipzig from types especially cast in imitation of the original, and published at St. Petersburg at the expense of Czar Alexander II. The original is on parchment, written in uncial characters (capitals), four columns to a page, and 48 lines on a page. It dates from the middle of the fourth century.

Codex Alexandrianus. Printed in type to represent the original manuscript. London, 1816. This facsimile version of the Alexandrian or Egyptian text of the Bible appeared in 1816, in four volumes, Vols. I–III containing the Old Testament, and Vol. IV the New Testament. The original manuscript was presented to King Charles I by Sir Thomas Roe, from Cyril, Lucar Patriarch of Constantinople. It was transferred to the British Museum in 1753. It is written on parchment in uncials without division of chapters, verses, or words. Tradition places the writing of this manuscript in the fourth century, but it is now generally assumed to date from the fifth century.

The Washington Manuscript of Deuteronomy and Joshua. (Facsimile). Edited by Professor Henry A. Sanders, of the University of Michigan. This manuscript, together with three other Biblical manuscripts, was acquired by the late Mr. Charles L. Freer, of Detroit, Michigan, from an Arabian dealer in Gizeh, near Cairo, Egypt, in 1906. It consists of 102 parchment leaves, and contains the Greek Septuagint version of Deuteronomy and Joshua, written in fine uncial letters in two columns of thirty-one lines on each page and is in good state of preservation. Professor Sanders, the editor of the manuscript, would connect it with the monastery of the Vinedresser, which was near the third pyramid, and believes it to have been written in the early part of the fifth century A. D. It is, therefore, one of the oldest and most important manuscripts of the Bible known. It has received the name Washington Manuscript because it was transferred to the Smithsonian Institution, and is deposited in the Freer Gallery of Art in Washington. (Pl. 37.)

The Washington Manuscript of the Four Gospels. (Facsimile.) Edited by Professor Henry A. Sanders, of the University of Michigan. The Manuscript, together with three other Biblical manuscripts, was acquired by Mr. Charles L. Freer, of Detroit, Michigan, from an Arabian dealer in Egypt in 1906. It consists of 187 parchment leaves, or 374 pages, and contains the four Gospels in the order of Matthew, John, Luke, and Mark, written in one column of 30 lines on each page, and in good state of preservation. The leaves of the manuscript were held between covers of two wooden panels painted with the portraits of the four Evangelists in the order in which their Gospels appear in the text, namely, Matthew and John on the left-hand board, Luke and Mark on the right-hand board.

Professor Sanders, the editor of the manuscript, would place it in the fourth century A. D. (Pl. 38.)

Ethiopic Version of the Bible. Photograph of original Bible preserved in the United States National Museum. This copy was obtained from King Theodore, of Abyssinia, by Lord Napier, and by him presented to General Grant. The Ethiopic version was made in the fourth century, probably by Frumentius, the Apostle of Ethiopia. It has 46 books in all, containing, in addition to the Canon, a large number of Apocryphal books.

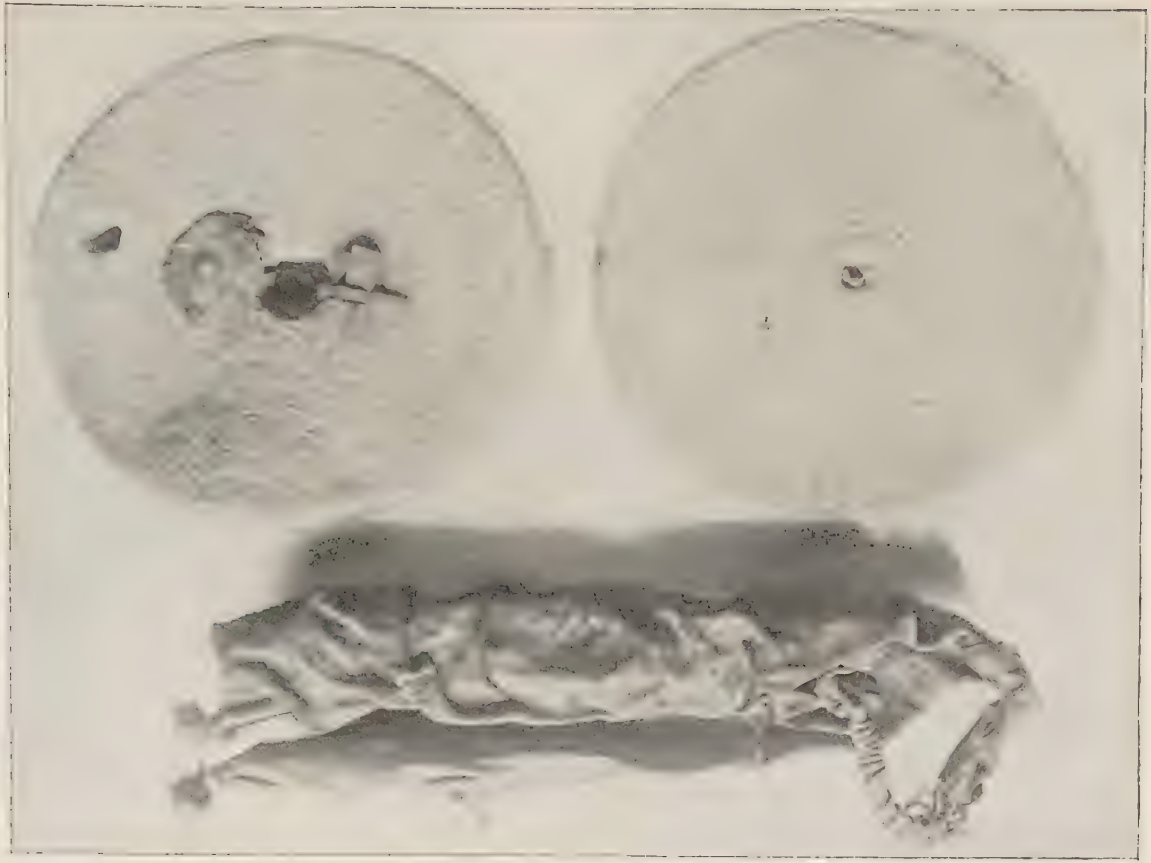
Latin Bible. Folio edition printed by Anthony Coburger in Nuremberg, Germany, 1478. The Latin Bible goes back to a Latin translation made from the Septuagint in the second century, and known as *Vetus Itala* or "Old Italic." The present version, however, is due to St. Jerome (Hieronymus), and was made by him in Bethlehem between 383 and 407 A. D. It was for a long time the Bible of the Western Church, and of a large part of the Eastern Church. Though no doubt based on the Septuagint, the translation of the Old Testament was made with reference to the original Hebrew, with which Jerome was well acquainted. The translation is commonly called the Vulgate, a name which was originally given to the Septuagint. It is still in use by the Roman Catholic Church. It was the first Bible ever printed, being produced by Gutenberg between 1450 and 1455, and constituted the first important specimen of printing with metal types. This Bible—one of the twelve Coburger Latin editions—is printed on 468 leaves in double columns, with fifty-one and fifty-three lines to the column. It has no title page, signatures, catchwords, or initials. The initial letters of paragraphs are painted by hand.

Greek and Latin New Testament of Erasmus. Editio princeps. Printed by Frebonius in Basel, Switzerland, 1516. The edition of the Greek New Testament, by Erasmus, was the first ever published, and became, with a few modifications, the *received text.* Luther's translation was based upon it. To the Greek original Erasmus added a corrected Latin version with notes. (Pl. 39.)

Arabic Version of Saadia Gaon. In Hebrew characters. The Pentateuch, edited by J. Derenbourg, Paris, 1893. Saadia Gaon was born at Fayum, A. D. 892, and died in 942. His translation of the Bible is rather a paraphrase and has a high exegetical value.

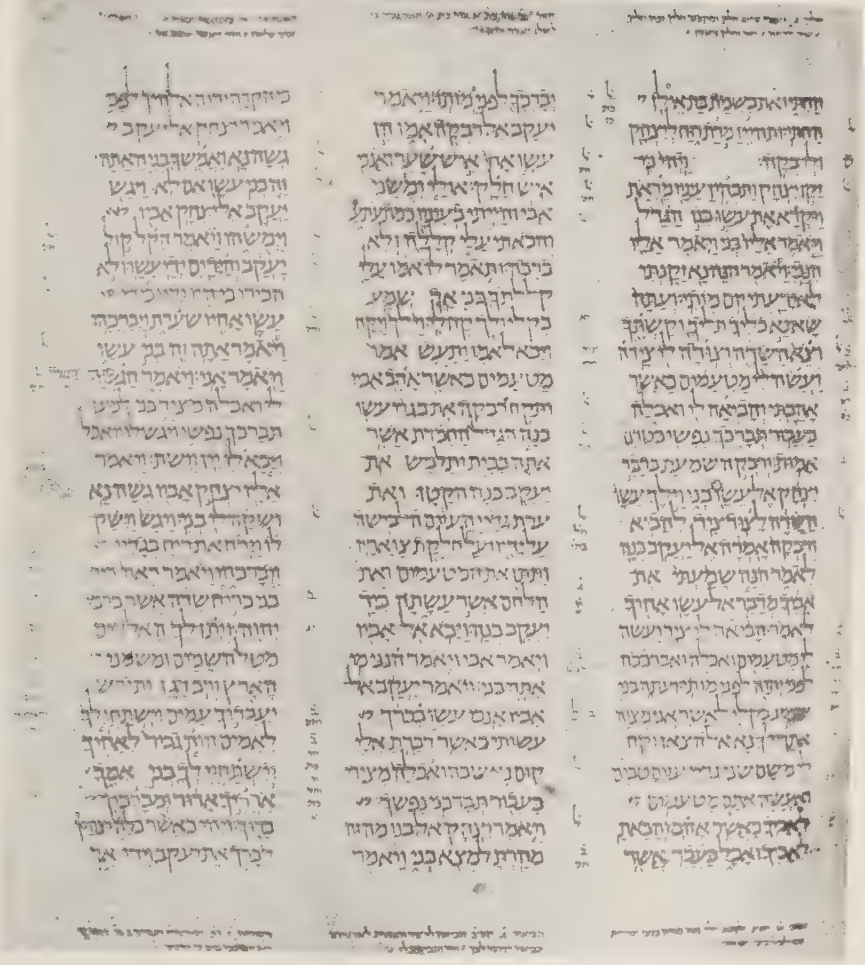
ENGLISH VERSIONS OF THE BIBLE.

The New Testament Translated by John Wycliffe, about 1380. Printed from a contemporary manuscript by William Pickering. London, 1848. John Wycliffe was born in Yorkshire, about 1320. He studied at Baliol College, Oxford, and was for some time master

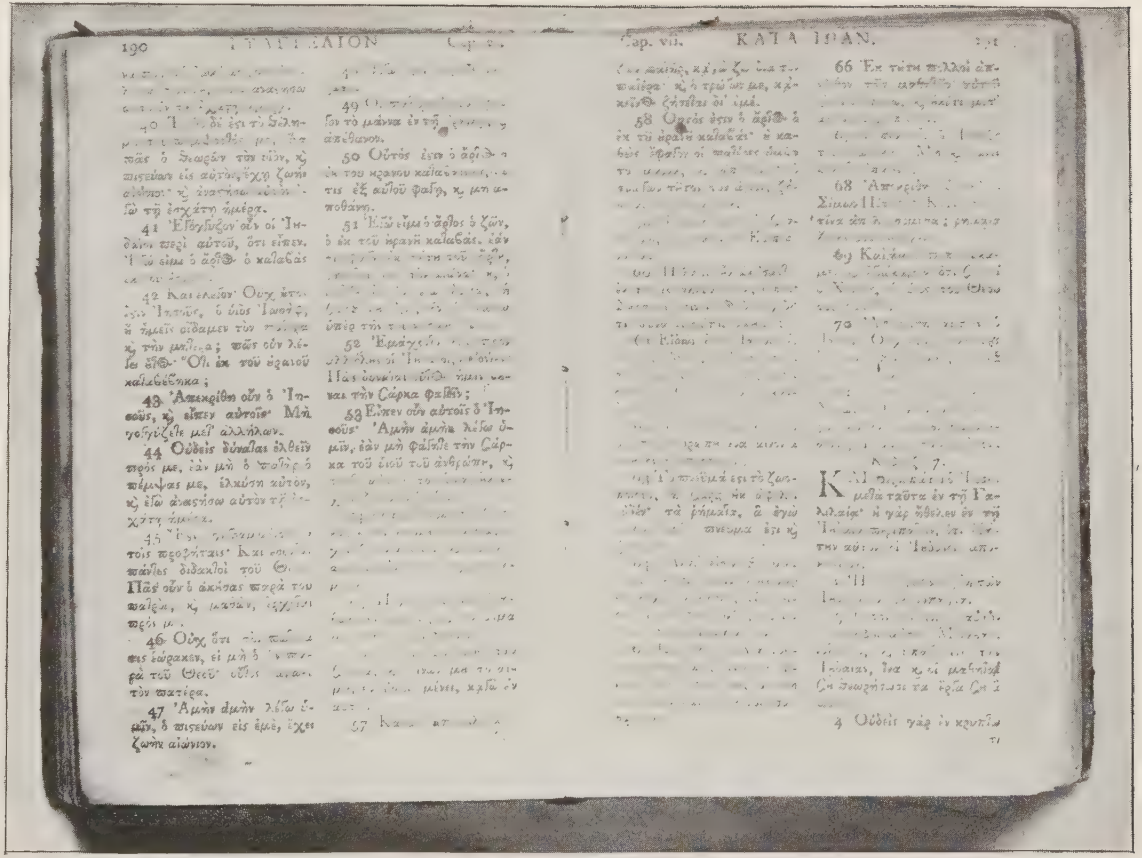


MILLSTONES, GOATSKIN WATER BAG.

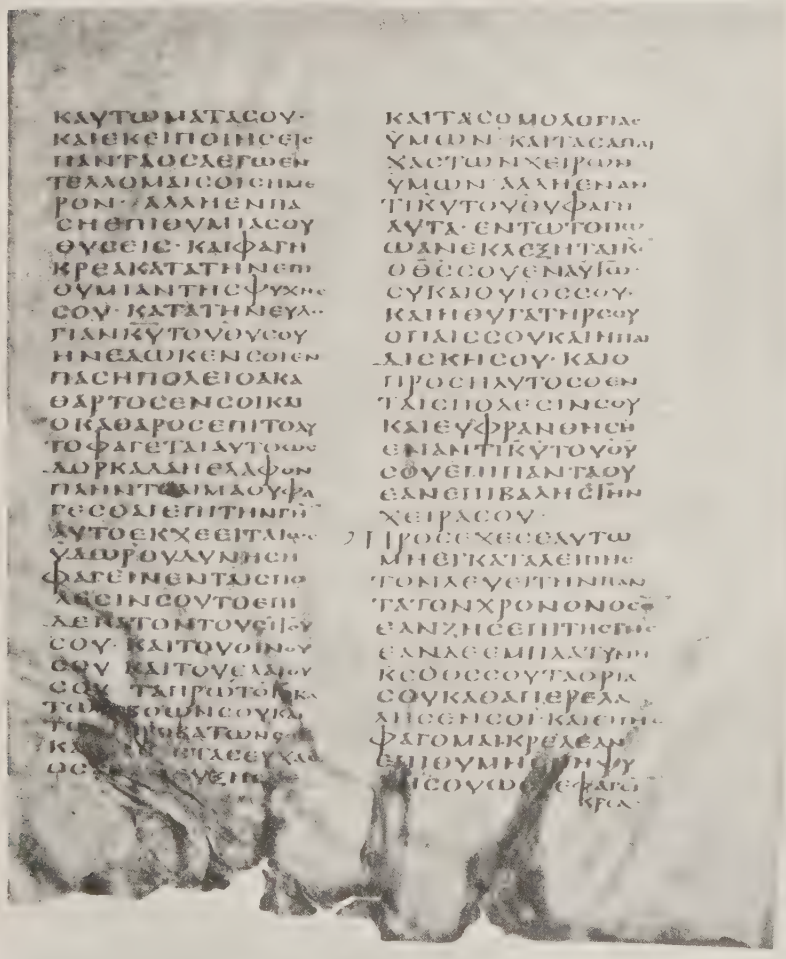
WOMEN GRINDING CORN BY HAND MILL.



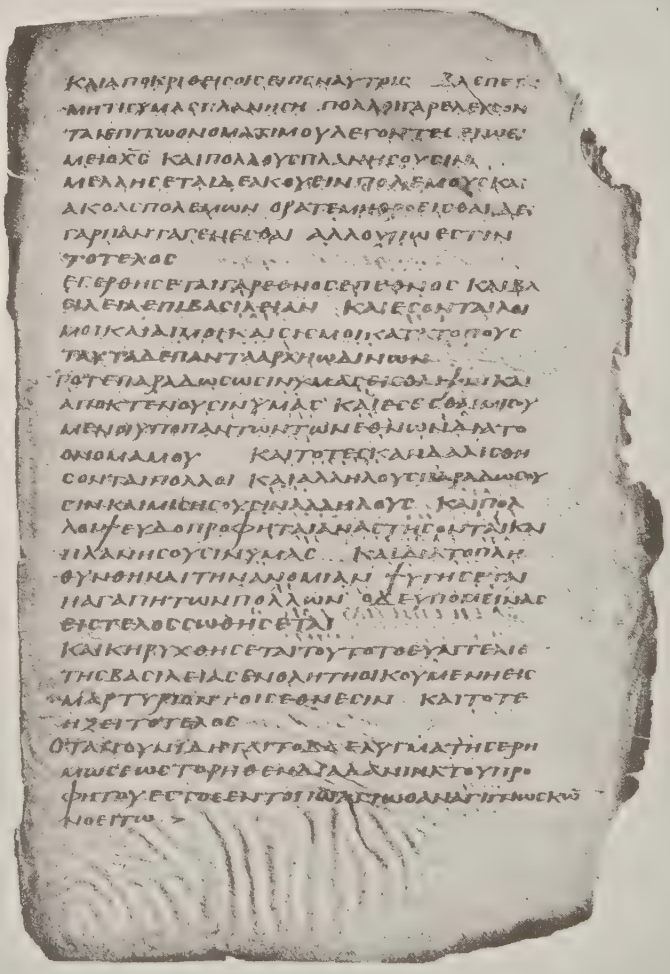
FACSIMILE OF THE ALEPPO CODEX.



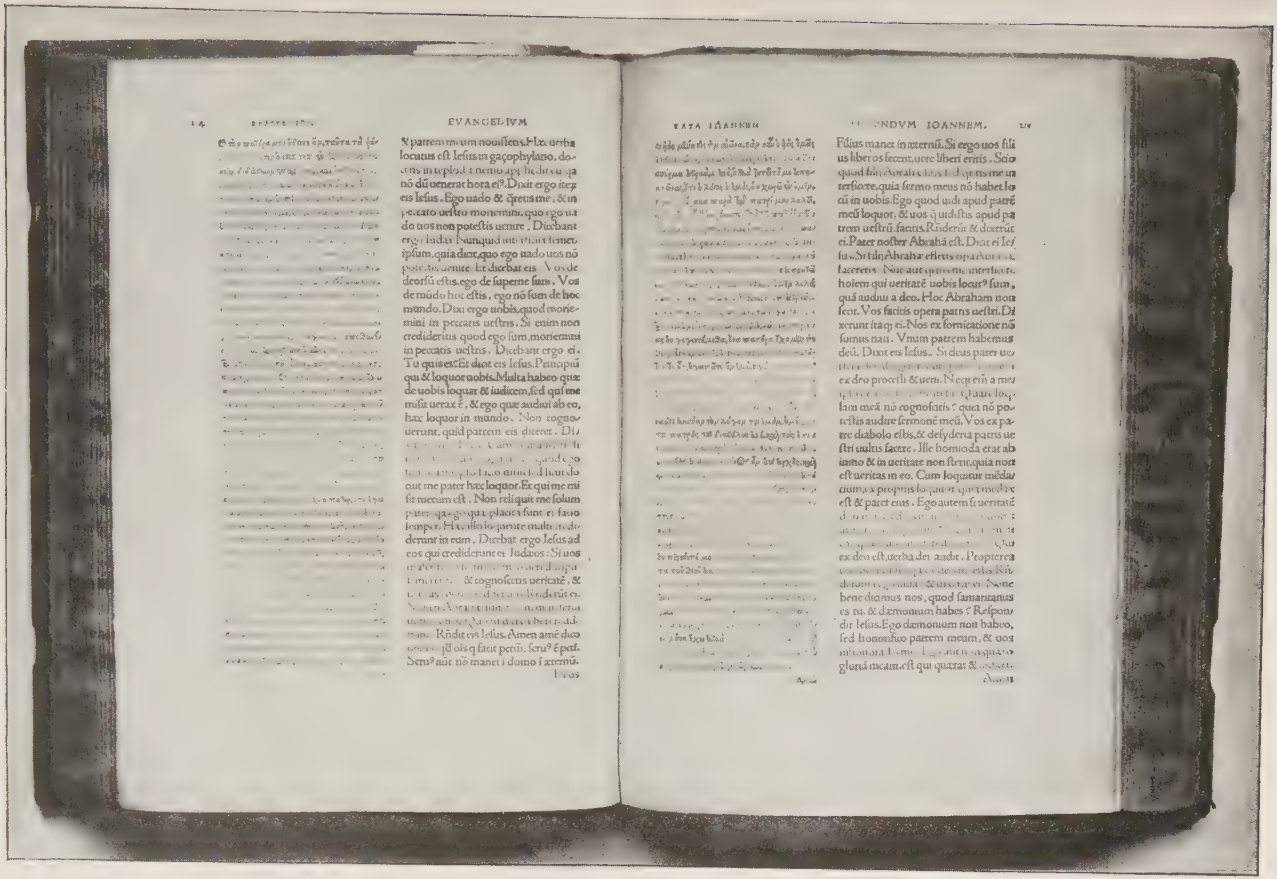
FIRST AMERICAN EDITION OF THE NEW TESTAMENT.



FACSIMILE OF THE WASHINGTON MANUSCRIPT OF DEUTERONOMY AND JOSHUA.



FACSIMILE OF THE WASHINGTON MANUSCRIPT OF THE FOUR GOSPELS.



GREEK AND LATIN NEW TESTAMENT OF ERASMUS.

THE

HOLY BIBLE:

CONTAINING THE

OLD TESTAMENT

AND THE *NEW.*

Tranſlated into the

INDIAN LANGUAGE,

AND

Ordered to be Printed by the *Commiſſioners of the United Colonies* in *NEW-ENGLAND,*

At the Charge, and with the Conſent of the

CORPORATION IN *ENGLAND*

For the Propagation of the Goſpel amongſt the Indians *in* New-England.

CAMBRIDGE:

Printed by *Samuel Green* and *Marmaduke Johnſon.*

MDCLXIII.

TITLE PAGE OF ELIOT'S INDIAN BIBLE.

of that college. He became later rector of Lutterworth, in Leicestershire, and was the foremost leader of the party of reform. He died in 1384. About 1380 he undertook, with the assistance of some of his followers, the translation of the entire Bible into English from the Latin of the Vulgate. His translation was, after his death, revised by one of his adherents. The present copy is assumed to represent the first version prepared by Wycliffe himself, or at least under his supervision.

Tyndale's New Testament. Facsimile by F. Fry. William Tyndale was born between 1484 and 1486, in Gloucestershire. He was educated at Oxford and afterwards at Cambridge. He went to Hamburg, and later joined Luther at Württemberg, where he finished the translation of the New Testament into English. The first edition was issued in 1525. His English style was very good and was largely retained in the Authorized Version. His translation was condemned by the English Bishops and was ordered to be burned. Tyndale was strangled for heresy at Antwerp in 1536, and his body burned.

The Gothic and Anglo-Saxon Gospels. With the versions of Wycliffe and Tyndale. Arranged by Rev. Joseph Bosworth, London, 1865. The *Gothic* version was made in the fourth century by Bishop Ulfilas (born 318 A. D., died about 381). It is said to have been a complete version with the exception of the book of Kings. It was probably completed about 360 A. D. Only fragments are preserved in the so-called Codex Argenteus, or "Silver Book," in the library of the University of Upsala, Sweden. The *Anglo-Saxon* version was begun by King Alfred, who translated the Psalms in the ninth century. The translation now extant dates to the tenth century.

Coverdale's Bible. Reprint by Baxter, 1838. Miles Coverdale was born at Coverham, in the North Riding of Yorkshire in 1488. He died at Geneva in 1569. His Bible was issued October 4, 1535, being the first complete Bible printed in the English language. It was not translated from the original tongues, but was based on the Latin version and on Luther's Bible.

The Genevan Version. Folio edition printed at London, 1597. This translation was made by nonconformists, who took up their residence at Geneva. William Whittingham acted as editor, and his assistants were Thomas Cole, Christopher Goodman, Anthony Gilby, Thomas Sampson, and Bishop Coverdale. Some add John Knox, John Bodleigh, and John Pullain, and state that the translators consulted Calvin and Beza. The first edition was printed at Geneva in 1560.

The Douay Version of the Bible. The Douay version was undertaken in 1568 by the British Roman Catholic refugees at Douay, Flanders, where a British Catholic college was established under the direction of William Allen and Gregory Martin. In 1578 the college, on account of political conditions, was moved to Rheims, France, where the first edition of the translation of the New Testament was issued in 1582. In 1593 the college was reestablished at Douay, and here the translation of the Old Testament was published in 1609–10. The Douay version is a close translation from the Latin Vulgate. It exercised some influence on the King James version of 1611, and was in turn, in its later revised editions, influenced by it.

King James or Authorized Version. Folio edition, printed at London by Robert Barker, 1613. The preparation of a new English Bible was decided upon at a conference held at Hampton Court, January 16 and 18, 1604. In that year King James I issued a commission to fifty-four eminent divines to undertake the work. It was not begun, however, until 1607, when seven of the original number had died. The forty-seven survivors were divided into six committees, two sitting at Oxford, two at Cambridge, and two at Westminster. In 1610 their work was completed and then revised by a committee of six. Although universally known as the authorized version, no record, either ecclesiastical or civil, has ever been found of such authorization. The first edition was printed by Robert Barker in 1611.

Revised Version. Revision of the text of 1611 was early advocated by men like Bishop Ellicott, Archbishop French, and Dean Alford. Efforts were also made from time to time in the House of Commons to have a Royal Commission appointed. In 1870 the upper house of the Canterbury Convocation, on the motion of Bishop Wilberforce, took the subject in hand and instituted the proceedings which finally secured the accomplishment of the work. In 1871 an American committee of cooperation was organized. The New Testament was completed in 1881 and the Old Testament in 1885.

Parallel New Testament. Revised version and authorized version. (Seaside Library.) The revised version of the New Testament appeared in England May 17, 1881, and in America May 20, 1881. The first half of the parallel Testament appeared in New York May 21, and the second half May 23.

The American Standard Version. Edited by the American Revision Committee, A. D. 1901. The American Committee of Revisers, cooperating with the British Committee, was organized in 1871. It consisted of thirty members, divided into Old and New Testament groups, with Professor William Henry Green, of Prince-

ton Theological Seminary, and ex-President Woolsey, of Yale College, as chairmen. They began work in 1872 and held for some time one session a month in the Bible House in New York City. The agreement between the British and American Committees was, briefly, as follows: The British revisers were to take the suggestions of the American Committee under special consideration and print, in an appendix, such preferences of reading and rendering as they declined to adopt, while the American revisers were not to issue an edition of their own for fourteen years after the publication of the British revision. The British revision was published in 1885, and, in 1901, the restricted period having elapsed, the American Standard Revision was issued. It contained many variations from the British, substituting words in good American standing for those differently used in England. It also altered the punctuation and paragraphing of the British revision, and inserted at the top of each page brief indications of the contents of that page, which is of value for ready reference.

Jewish-English Version of the Old Testament. A new translation of the Old Testament prepared during the years 1908 to 1915 by a group of American Jewish scholars, with the aid of previous versions and with constant consultation of Jewish authorities. It aims to combine the spirit of Jewish tradition with the results of Biblical scholarship, ancient, medieval, and modern. Published by the Jewish Publication Society of America, Philadelphia, Pa.

TRANSLATIONS OF THE BIBLE IN FOREIGN LANGUAGES.

Luther's Bible. German translation, made by Martin Luther. Edition of 1554. The New Testament appeared in 1522 and the Old Testament, in parts, between 1523 and 1532. The complete Bible appeared in 1534. Previous to Luther's version there were in use at least 10 distinct German versions, literal translations of the Latin Bible. Luther worked from the original tongues, and yet succeeded in giving the Bible a real German dress and a style that would appeal to German readers. Luther's translation was of prime importance in bringing about the Reformation, and is also the foundation of the German literary dialect.

German Bible. Containing the Old and the New Testament and the Apocrypha of the Old Testament in Luther's translation, with numerous woodcut illustrations. The translation is preceded by an index and explanations of the proper names occurring in the Bible, a synopsis of the principal doctrines, and an historical and chronological list. At the head of each book and chapter is a summary of their respective contents. Bound in vellum, richly tooled, with ornamental brass clasps. Printed in Frankfort on the Main in 1704.

The Christopher Sauer Bible. The Bible printed by Christopher Sauer in Germantown, Pa., in 1743 was the first edition of the Scriptures published in America in a European tongue. Its issue was announced in Bradford's "Weekly Mercury" for April 1, 1742, and in Franklin's "Pennsylvania Gazette" for April 31, 1741. This German edition of the Bible follows, with a few exceptions, the version of Luther. It contains the Old and the New Testament and the Apocrypha, including the third and fourth Ezra and the third Maccabees. Each chapter is preceded by a summary of its contents, and references to parallel passages are noted.

Spanish Old Testament. Amsterdam, Holland, 1661 (5421). The first edition of this translation was printed in the middle of the sixteenth century. It bears the title: "The Bible in the Spanish language, translated word for word from the Hebrew, examined by the Inquisition, with the privilegium of the Duke of Ferrara." It is therefore generally known as the Ferrara Bible. The copies of this translation are divided into two classes—one appropriate for the use of the Jews, the other suited to the purposes of the Christians. The translation is extremely literal, and the translator has indicated with an asterisk the words which are in Hebrew equivocal or capable of different meanings.

Dutch Bible. Printed at Dort (Dordrecht), Holland, in 1741, with illustrations and marginal comments. This version of the Bible was ordered by the Synod of Dort (1618–19), which appointed three theologians for the translation of the Old Testament and three for that of the New Testament, besides two revisers from each province. The work of translation was finished in 1635.

Eliot's Indian Bible. Facsimile reprint. Washington, D. C., 1890. John Eliot, "the apostle of the Indians," was born in England in 1604 and received his education at Cambridge. In 1631 he removed to America and settled at Roxbury, Massachusetts, as minister, where he remained until his death in 1690. He became interested in the conversion of the Indians of New England, whom he believed to be the descendants of the lost tribes of Israel, and determined to give them the Scriptures in their tribal tongue, which was the Natick dialect. He completed the translation of the New Testament in 1661 and that of the entire Bible in 1663. It was printed in Cambridge, Massachusetts, by Samuel Green and Marmaduke Johnson, "ordered to be printed by the Commissioners of the United Colonies in New England, At the Charge and with the Consent of the Corporation in England for the Propagation of the Gospel amongst the Indians in New England." Eliot's Indian Bible was the first ever printed in America, and the entire translation is stated to have been written with one pen. Eliot also published an Indian

grammar and a number of other works, mostly relating to his missionary labors. The Natick dialect, in which the translation of the Bible was made, is now extinct (pl. 40).

Fiji Gospels. Printed at Vuda, Fiji Islands, 1847. The Fiji group of islands is located in the South Pacific Ocean. It comprises over 200 islands, of which about 80 are inhabited. Since 1874 the Fiji Islands have been a British dependency; they have a population of about 125,000. Christianity was introduced in the islands by Wesleyan missionaries in 1835.

Armenian Bible. The first translation of the Bible into the Armenian language was made from the Syriac version in the fifth century by Mesrob (354–441), the reputed inventor of the Armenian alphabet and founder of Armenian literature, and the patriarch Sahak (Isaac). The present translation was printed in New York in 1870. Bound in black Morocco, richly gold tooled, with gilt edges.

The Bible in the Turkish Language. Printed in Constantinople in 1878. Bound in black roan, richly tooled.

The New testament in the Korean Language. This is the first issue of the Scriptures in the Korean tongue. Printed in Seoul, Korea, in 1900.

BIBLES OF HISTORICAL INTEREST.

Biblia Pauperum (Bible of the Poor). A series of cuts (from 34 to 50) illustrating the leading events in the history of Christ, each with representations of supposed parallels from the Old Testament, and accompanied with explanatory texts. Thus, on the page exhibited in the Museum, in the center is the transfiguration of Christ (Matthew xvii, 1–9; Mark ix, 2–10; Luke ix, 28–36); to the left, Abraham receiving the three angels (Genesis xviii); to the right; Nebuchadnezzar and Hananiah, Mishael, and Azariah (Shadrach, Meshach, and Abed-nego) in the furnace (Daniel iii). Above are the busts of David and Isaiah; underneath, of Malachi and Habakkuk; and below, the explanatory text. Such Bibles were in vogue during the Middle Ages, until, through the invention of printing, the complete Scriptures were made accessible to the people. This copy is a facsimile of the edition of Hans Sporer, 1471, at Nuremberg, Germany.

Cromwell's Soldier's Pocket Bible. Facsimile reprint. Compiled by Edmund Calamy, and issued for the use of the Army of the Commonwealth, London, 1643. It has frequently been stated that every soldier in Cromwell's army was provided with a pocket Bible, and it was supposed that an especially small copy was used. In 1854 the late Mr. George Livermore of Cambridgeport, Mass., discovered that the Bible which Cromwell's soldiers carried was not

the whole Bible, but the soldier's pocket Bible, which was generally buttoned between the coat and the waistcoat next to the heart. It consists of a number of quotations from the Geneva version (all but two from the Old Testament) which were especially applicable to war times. Only two copies of the original of this work are known to exist—one in America and the other in the British Museum. The work was reissued in 1693 under the title "The Christian Soldier's Penny Bible." The only copy extant, so far as known, is in the British Museum.

Bishop Asbury's New Testament. With hundreds of the texts for his sermons marked in his own handwriting. Francis Asbury (born in Staffordshire, 1745; died in Virginia, 1816) was the first Bishop of the Methodist Church ordained in America. He was sent as a missionary by John Wesley in 1771, and in person organized the work of his denomination in the entire eastern portion of the United States, performed the first ordination in the Mississippi valley, and in 1784 founded the first Methodist college.

The Life and Morals of Jesus of Nazareth. Extracted textually from the Gospels in Greek, Latin, French, and English, by Thomas Jefferson, being the so-called Jefferson Bible. A compilation made by Jefferson about 1819, consisting of passages from the Gospels, cut out and pasted in a volume according to a scheme of his own. A concordance of the texts is given in the front and the sources of the verses in the margins; the section of the Roman law under which Christ was tried is also cited. All of these annotations, as well as the title-page and concordance, are in Jefferson's own handwriting. Two maps, one of Palestine and another of the ancient world, are pasted in the front. Jefferson long had the preparation of this book in mind. On January 29, 1804, he wrote from Washington to Doctor Priestley: "I had sent to Philadelphia to get two Testaments (Greek) of the same edition, and two English, with a design to cut out the morsels of morality, and paste them on the leaves of a book." Nearly 10 years later (October 13, 1813), in writing to John Adams, he stated that he had for his own use cut up the Gospels "verse by verse out of the printed book, arranging the matter which is evidently his (Christ's)." In the same letter he describes the book as "the most sublime and benevolent code of morals which has ever been offered to man." It is said that it was Jefferson's original idea to have this compilation translated for use among the Indians (pls. 41 and 42).

The Two Copies of the English New Testament from which Jefferson Made the Clippings for the English Version of the "Life and Morals of Jesus of Nazareth." Printed in Philadelphia, 1804. Jefferson refers to these New Testaments in a letter of January 29, 1804,

addressed from Washington to Doctor Priestley: "I had sent to Philadelphia to get two Testaments (Greek) of the same edition, and two English, with a design to cut out the morsels of morality and paste them on the leaves of a book."

Jewish Soldier's Pocket Bible. Published by the Jewish Publication Society of America, Philadelphia, Pa., 1918. This volume contains readings from the Holy Scriptures for Jewish soldiers and sailors in the service of the United States, consisting mainly of passages relating to God's creation and maintenance of the world, His providence, and His guidance of the destinies of nations. Bound in khaki.

Hieroglyphic Bible. Published by Joseph Avery, Plymouth; printed by George Clark & Co., Charlestown, 1820. A number of Hieroglyphic Bibles have been printed in America, the first being that of Isaiah Thomas at Worcester, Mass., in 1788. Words in each verse are represented by pictures, the whole being designed "to familiarize tender age, in a pleasing and diverting manner, with early ideas of the Holy Scriptures." (Pl. 43.)

Above, on the wall of the cases, is exhibited a collection of musical instruments mentioned in the Bible. Scarcely any authentic information is preserved concerning the shape or the manner of playing on the musical instruments named in the Bible. The only ancient representation of any Hebrew musical instrument extant is that of the *haçoçera*, or trumpet, on the Arch of Titus at Rome. There is no doubt but that the *shofar* or ram's horn, which is still used in the synagogue, has conserved its antique form, but it may be assumed that the musical instruments of the Hebrews resembled those of the Assyrians and Egyptians, some of which are sculptured on the monuments, and that the instruments still used in Palestine, Syria, and Egypt, differ but little, if at all, from those employed in ancient times.

MUSIC AND MUSICAL INSTRUMENTS IN THE BIBLE.

To music a high position is assigned in the Bible. Its invention is recorded in the opening chapters of the Scriptures (Genesis iv, 21), and in the Revelation of St. John (v. 9; xv, 2 ff) it serves to express the consummation of beatitude. From the earliest times music was used as expressive of the joys and sorrows of daily life in Israel. It was the pastime of the shepherd (I Sam., xvi, 18); it formed a principal attraction of the social gatherings of youth at the city gates (Lamentations, v, 14); it accompanied the celebration of the festivals of the harvest and vintage (Isaiah xvi, 10; Judges xxi, 21); the victors in battle were received on their return with "singing, dancing, and timbrels" (Exodus xv, 21; Judges xi,

34; I Sam., xviii, 6); it contributed to the pleasure and festivity of the banquet (Isaiah v, 12; Amos vi, 5; II Sam., xix, 35). It was the indispensable accompaniment of every festal occasion (Genesis xxxi, 27; Luke, xv, 25). Above all, music constituted an important feature of religious worship.

In earlier time only two instruments—the trumpet (*haçoçera*) and the ram's horn (*shofar*)—are mentioned as having been used by divine ordinance (Numbers x, 2 ff; Levit., xxiii, 24; xxv, 9). An extensive use of music, both vocal and instrumental, in religious service was inaugurated under David. Under his direction 4,000 Levites under 288 leaders were organized into a chorus and orchestra, who in 24 divisions provided for the music of the sanctuary (I Chron., xxiii, 5; xxv, 7). Solomon had lutes and harps of sandalwood prepared for the singers (I Kings, x, 12). Among the later kings, Hezekiah and Josiah are especially mentioned as having given much attention to the musical services of the Temple (II Chron., xxix, 25; xxxv, 15). Music at service was not altogether neglected, even during the depressed condition of the people subsequent to the captivity (Nehem., xi, 17, 22; xii, 28). And from Hebrew post-Biblical writings it is known that it formed a prominent feature of Jewish worship in the time of Christ.

The musical instruments mentioned in the Bible were, like those of antiquity in general, of three kinds:

1. Wind instruments.

2. Stringed instruments, which were always played with the fingers or with the plectrum, and not, like the modern violin, with a bow.

3. Instruments of percussion, which were beaten or shaken to produce sound.

The instruments exhibited are as follows:

I.—INSTRUMENTS OF PERCUSSION.

(1) Round tabret (Hebrew, *tof*, Arabic, *duff*, which agrees with the Hebrew and is the parent of the Spanish *aduffa*). Beirut, Syria (where it is called *rikk*). The tabret or timbrel was and is still one of the most common musical instruments in the Orient. It is often mentioned throughout the earlier history of Israel (Genesis xxxi, 27; Judges xi, 34, etc.). It was used chiefly by women, especially in dances and public processions (Exodus xv, 20; I Samuel xviii, 6), but appears to have had no place in the religious services of the Tabernacle or Temple. According to representations on Egyptian monuments, the timbrel was either round or four-sided in shape.

(2) Four-sided tabret. Morocco, Africa.

(3) Kettledrum (Arabic, *naggarah*). Cairo, Egypt. The kettledrum is used in military bands, orchestras, and in short solo pas-

sages. It is also employed by the Dervishes to produce excitement in their devotions. The kettledrum is sounded with blows from a soft-headed, elastic mallet, stick, or a leather thong.

(4) Cymbals (Hebrew, *meçiltayim*, *çilçelim*). Cairo, Egypt. Cymbals are frequently enumerated among the musical instruments employed in the Temple (I Chronicles xv, 16, 19, 28; xvi, 5, 42; xxv, 6; II Chronicles v, 13; xxix, 25, etc.). The cymbals were of two kinds. One consisted of two large plates of metal with wide flat rims and were played by being strapped to the hands and clashed together. The others were conical, or cup-like, with thin edges, and were played by bringing down the one sharply on the other while held stationary, eliciting a high-pitched note. The Hebrew names, which denote a jingling sound, can also be applied to:

(5) Castanets (Hebrew, *çilçelim;* Syrian, *faggeishah*). Beirut, Syria (pl. 44).

II.—WIND INSTRUMENTS.

(1) Ram's horn (Hebrew, *shofar*). The shofar, in the English versions usually inaccurately translated trumpet, or even more inaccurately, cornet, is first mentioned in the Bible in connection with the giving of the law on Sinai (Exodus xix, 16; xx, 18). Its use is ordered for the announcement of the new moon and solemn feasts (Numbers x, 10, compare Psalms lxxxi, 4), and the proclamation of the year of release (Leviticus xxv, 9). New Year's Day (the first of the seventh month, or *Tishri*) is called a "memorial day of blowing" (Leviticus xxiii, 24; Numbers xxix, 1). The shofar also served in religious processions (II Samuel vi, 15; I Chronicles xv, 28), and along with other musical instruments as an accompaniment to the song of praise (Psalms xcviii, 6; cl, 3, compare Psalms xlvii, 6). But the most ancient and most frequent use of the shofar was for military purposes, to give the signal for the rallying of the people and for attacking and pursuing the enemy (Numbers x, 2 ff; Joshua vi, 4; Judges iii, 27; vii, 18, 20; I Samuel xiii, 3). The shofar is not only the sole instrument of those mentioned in the Bible which is still employed by the Jews in their religious services of the synagogue during the penitential month of Elul (July-August); on New Year's Day or *Rosh ha-Shanah*, the first of *Tishri* (August-September); and on Atonement Day, or *Yom Kippur*, the tenth of *Tishri;* but is also, according to authorities on musical instruments, the oldest form of wind instrument known to be retained in use. It is usually made of a ram's horn, though the goat's horn is also employed (pl. 45, fig. 2).

(2) Trumpet (Hebrew, *haçoçerah*). Morocco, Africa (where it is called *n'feer*). The trumpet was the first instrument expressly ordered in the Pentateuch. At first there were but two, made of

silver (Numbers x, 1–10). Solomon increased their number to one hundred and twenty (II Chronicles v, 12). It was almost exclusively a priestly instrument. Its primary use was for giving signals for the people to assemble, but was appropriated to religious services (II Kings xii, 14; II Chronicles xiii, 12, 14). According to the representation on the Arch of Titus, the trumpet was narrow and straight and had at the bottom a bell-like protuberance (pl. 46).

(3) Flute or pipe (Hebrew, *halil*). Damascus, Syria (where it is called *shubab*). The pipe or flute was a favorite instrument of the ancients. In its simplest form it was a reed, or variety of wood in the shape of a reed, about 18 inches in length, bored throughout evenly and pierced with holes in the sides for notes. Sometimes two were bound together. The flute was not used in religious services, but it is mentioned among others in the Bible as employed on festival occasions, as also on those of mourning (I Samuel x, 5; I Kings i, 40; Isaiah xxx, 29; Matthew ix, 23; xi, 17; Revelation xviii, 22) (pl. 45, fig. 4).

(4) Double flute. Bethlehem, Palestine. This instrument is assumed by some to represent the *sumponiah* (symphony) of Daniel iii, 5, 10, 15. The English versions give dulcimer, though the margin of the Revised Version gives bagpipe. *Sumponiah* is supposed by some to be a translation of the Hebrew *'ugab*, but the latter possibly represents pan pipes (pl. 45, fig. 3).

(5) Reeds or pan pipes. Cairo, Egypt. The reeds, now called in Syria *Mijwiz* or *Naigha*, are enumerated in Daniel iii, 5, 7, 10, 15, under the name of *mashrokitha* (English version, flute), among the instruments of the Babylonians. Some consider them the Hebrew *'ugab* (Genesis iv, 21). They were known to the Greeks under the name of *syrinx* (Latin *fistula*) (pl. 45, fig. 3).

(6) Bagpipe. Tunis, Africa, where it is called *zaida*. Supposed by some to represent the Hebrew *'ugab*, one of the first musical instruments mentioned in the Bible (Genesis iv, 21); others consider *'ugab* to mean a sort of a syrinx. The Authorized Version renders it by "organ," the Revised by "pipe." The bagpipe originated in the East, was known to the Greeks and Romans, was popular throughout the middle ages, and is still used in many eastern countries, and among the country people of Poland, Italy, the south of France, and in Scotland and Ireland (pl. 47).

III. STRINGED INSTRUMENTS.

(Not represented by specimens.)

The stringed instruments mentioned in the Bible are:

(1) Harp. The Hebrew word *kinnor* which is adopted for harp, occurs in the opening chapters of the Bible (Genesis iv, 21). It

was the especial instrument of David (I Samuel xvi, 23). Later it was one of the important instruments of the temple orchestra (I Chronciles xv, 16; II Chronicles xxix, 25). The exiles hung their harps on the willows by the waters of Babylon (Psalms cxxxvii, 2). To judge from representations on Egyptian monuments and Jewish coins of the second century B. C., the *kinnor* resembled the Greek *kithara* more than the modern trigonal harp, and as a matter of fact the Hebrew *kinnor* is usually rendered *kithara* by the Septuagint, the oldest Greek version of the Old Testament. Jewish coins show lyres with three, five, and six strings. A similar instrument was also in use among the Assyrians. In its smaller form it could easily be carried about in processions, as the representations on the monuments, both Egyptian and Assyrian, show.

(2) Psaltery (Hebrew, *nebel*). The psaltery, or lute, is often mentioned in the Bible together with the harp, though it seems to have been less used than the latter. It is likely that the psaltery resembled what is now known in the East as the tamboora, or guitar, an instrument which also figures largely on the Egyptian and Assyrian monuments. In its present shape the psaltery is thus described: "In its most complete and perfect form, this instrument is 3 feet 9 inches long, has ten strings of fine wire and 47 stops. It is played with a plectrum, and is often inlaid with mother-of-pearl and valuable woods. It is oftener, however, of smaller size and less costly materials." (Van Lennep, Bible Lands, p. 612.) The church father Jerome states that the *nebel*, whose name became *nabla* and *nablium* in Greek and Latin, had the form of the Greek letter Δ, that is, was a triangular pointed harp.

On the bottom of one case is a collection of Turkish and Persian glazed and enameled tiles.

37. Contains a collection of pottery from various localities.

38. In the alcove, Round Altar of the Twelve Gods. Cast from an original of marble in the Museum of the Capitol, Rome. The twelve gods, with their attributes, represented in relief, are, in order from right to left, as follows: 1. Zeus, with scepter and thunderbolt; 2. Hera; 3. Athene, with lance, helmet, and aegis; 4. Heracles, with lion's skin, club, and bow; 5. Apollo, with bow and quiver; 6. Artemis, with bow; 7. Ares, with shield and helmet; 8. Perhaps Aphrodite; 9. Probably Demeter, with scepter and torch; 10. Hermes, with cap, wand, wings, and ram; 11. Poseidon, with trident; 12. Hephaestus (Vulcan), with hammer.

39–43. The last five wall cases are given over to Greco-Roman sculptures.

Above, on the wall of the cases, are votive reliefs, sepulchral stelae, and reduced casts in frames of the Pergamon altar reliefs.

These reliefs belong to the altar of Zeus Soter (the Savior), which was probably erected by King Eumenes II (197–159 B. C.) on the Acropolis of Pergamon, Asia Minor. The altar is considered one of the most magnificent and most characteristic monuments of the Hellenistic age. It was raised upon a platform about 16 feet high and nearly square, measuring about 123 feet 7 inches by 113 feet 6 inches. One side of the platform was pierced by a broad staircase leading up to the altar, which stood in the center, surrounded, except at the head of the staircase, by an Ionic colonade. The platform was encircled by a band of sculptures in high relief, about 7 feet 6 inches high and probably about 400 feet long, representing the battle between the gods and the titans, or giants, the serpent-legged sons of *Gaia* (Earth), symbolizing the struggle between order and the unorganized natural forces, which were at work within the bosom of the earth at the creation of the world. The ruins of the altar and its decorations of marble were discovered and excavated by the Germans during the years 1878–1880, under the superintendence of the architect, Carl Humann. The fragments of over 350 feet of the relief, which have been brought to light in these excavations, are now in the Museum of Berlin. The following seven groups from the battle are represented:

(1) Zeus group. Zeus battling with three giants.

(2) Athene group. The warlike daughter of Zeus is assisted in her fight with a young winged giant by Erichthonios, her foster child, and Nike (Victory). Between them Gaia emerges from the ground raising her hand in supplication for mercy for her sons.

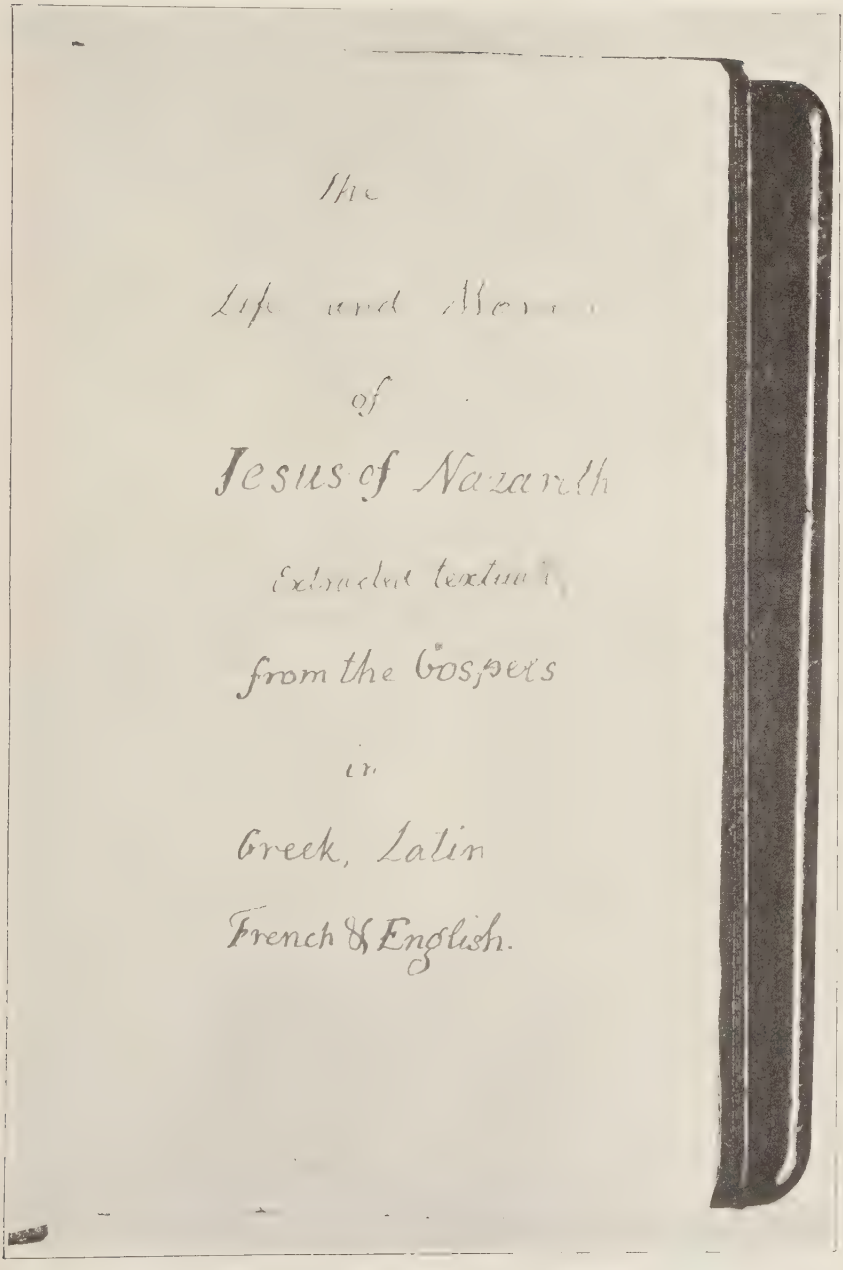
(3) Demeter and Persephone group with torch and sword and assisted by a dog fighting three giants.

(4) Hecate and Artemis group. Hecate, the goddess of night and the underworld, is armed with shield, sword, and flaming torch, while Artemis (Diana), the goddess of the moon and the chase, is equipped with the bow. Both are assisted by dogs.

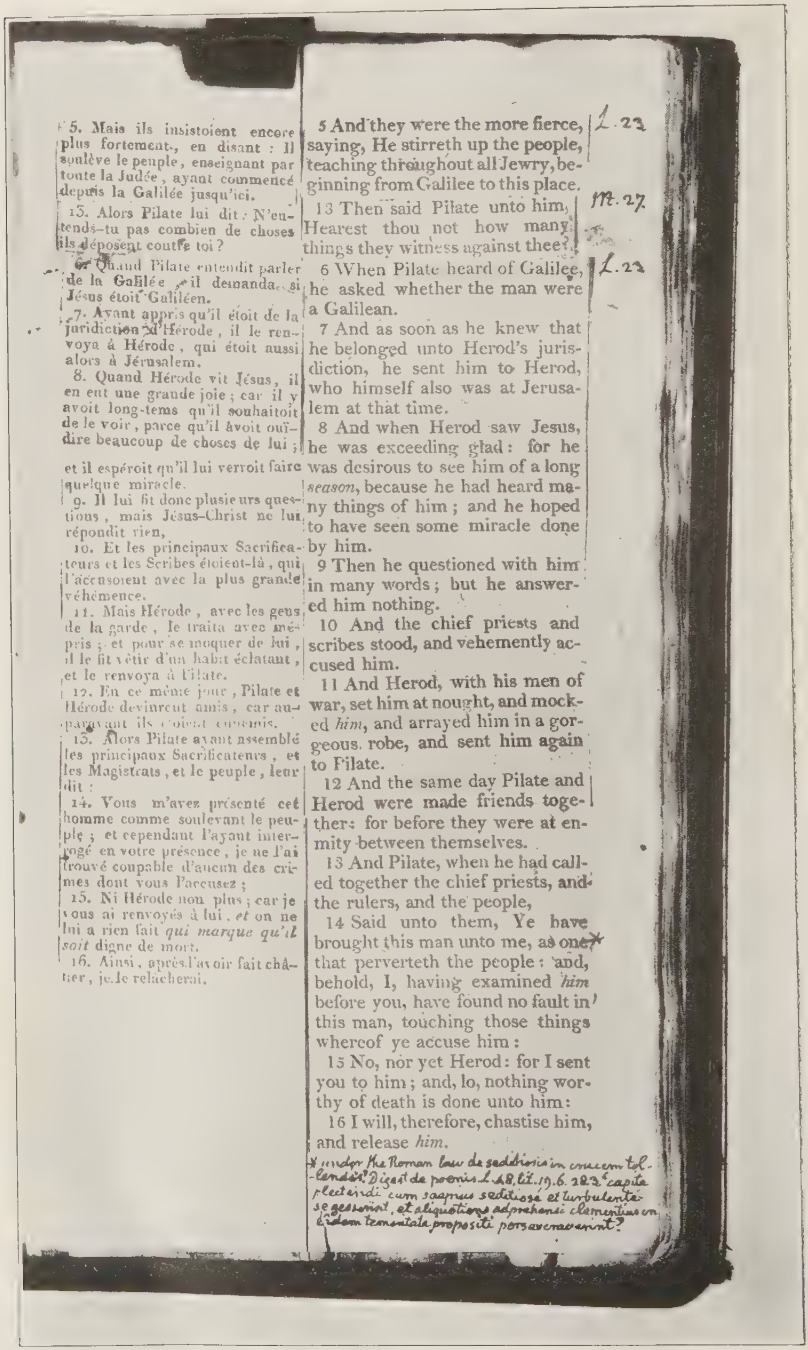
(5) Helios group. Helios, the sun god, is leading his four-horse chariot over the battle field. In front rides Eos (Aurora, dawn), sword in hand, on horseback, while behind is another of the attendants (Hours) on Helios, in flowing garment with torch.

(6) The snake vase group. A goddess seizes the shield of a giant with her left hand while her right hand holds a vase encircled by snakes, which she is about to hurl at him. One snake is already coiling over him. At the left another winged goddess is about to drive a sword into the neck of a snake-legged giant, whom she holds by the hair of his head.

(7) Cybele group. Cybele, the "Great Mother of the Gods," enters the contest riding on her lion. At her side hovers the eagle of Zeus. She is in the act of drawing an arrow from her quiver.



TITLE PAGE OF JEFFERSON'S NEW TESTAMENT.



5. Mais ils insistoient encore plus fortement, en disant : Il soulève le peuple, enseignant par toute la Judée, ayant commencé depuis la Galilée jusqu'ici.

13. Alors Pilate lui dit : N'entends-tu pas combien de choses ils déposent contre toi ?

6. Quand Pilate entendit parler de la Galilée, il demanda si Jésus étoit Galiléen.

7. Ayant appris qu'il étoit de la juridiction d'Hérode, il le renvoya à Hérode, qui étoit aussi alors à Jérusalem.

8. Quand Hérode vit Jésus, il en eut une grande joie ; car il y avoit long-tems qu'il souhaitoit de le voir, parce qu'il avoit ouï-dire beaucoup de choses de lui ; et il espéroit qu'il lui verroit faire quelque miracle.

9. Il lui fit donc plusieurs questions, mais Jésus-Christ ne lui répondit rien,

10. Et les principaux Sacrificateurs et les Scribes étoient-là, qui l'accusoient avec la plus grande véhémence.

11. Mais Hérode, avec les gens de la garde, le traita avec mépris ; et pour se moquer de lui, il le fit vêtir d'un habit éclatant, et le renvoya à Pilate.

12. En ce même jour, Pilate et Hérode devinrent amis, car auparavant ils étoient ennemis.

13. Alors Pilate ayant assemblé les principaux Sacrificateurs, et les Magistrats, et le peuple, leur dit :

14. Vous m'avez présenté cet homme comme soulevant le peuple ; et cependant l'ayant interrogé en votre présence, je ne l'ai trouvé coupable d'aucun des crimes dont vous l'accusez ;

15. Ni Hérode non plus ; car je vous ai renvoyés à lui, *et* on ne lui a rien fait *qui marque qu'il soit* digne de mort.

16. Ainsi, après l'avoir fait châtier, je le relâcherai.

5 And they were the more fierce, saying, He stirreth up the people, teaching throughout all Jewry, beginning from Galilee to this place. L. 23

13 Then said Pilate unto him, Hearest thou not how many things they witness against thee? M. 27

6 When Pilate heard of Galilee, he asked whether the man were a Galilean. L. 23

7 And as soon as he knew that he belonged unto Herod's jurisdiction, he sent him to Herod, who himself also was at Jerusalem at that time.

8 And when Herod saw Jesus, he was exceeding glad: for he was desirous to see him of a long *season*, because he had heard many things of him; and he hoped to have seen some miracle done by him.

9 Then he questioned with him in many words; but he answered him nothing.

10 And the chief priests and scribes stood, and vehemently accused him.

11 And Herod, with his men of war, set him at nought, and mocked *him*, and arrayed him in a gorgeous robe, and sent him again to Pilate.

12 And the same day Pilate and Herod were made friends together: for before they were at enmity between themselves.

13 And Pilate, when he had called together the chief priests, and the rulers, and the people,

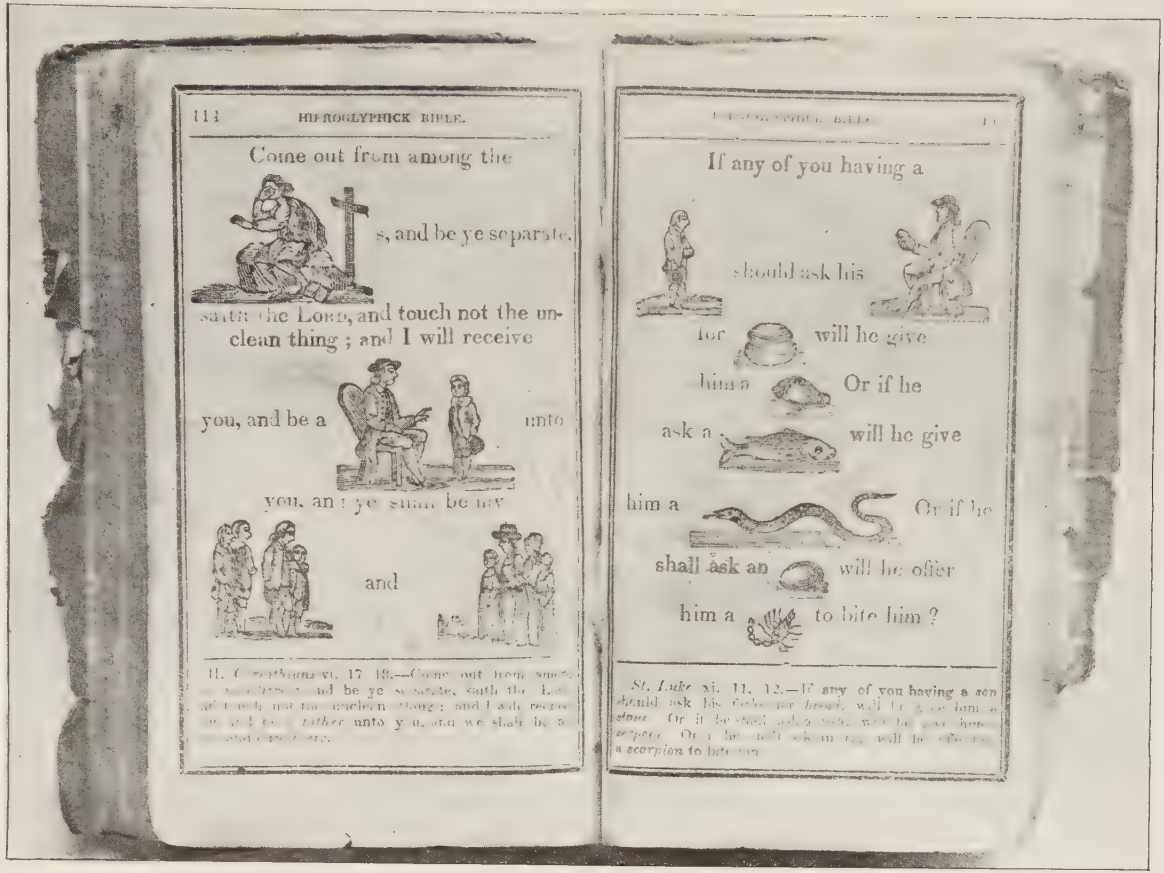
14 Said unto them, Ye have brought this man unto me, as one* that perverteth the people: and, behold, I, having examined *him* before you, have found no fault in this man, touching those things whereof ye accuse him:

15 No, nor yet Herod: for I sent you to him; and, lo, nothing worthy of death is done unto him:

16 I will, therefore, chastise him, and release *him*.

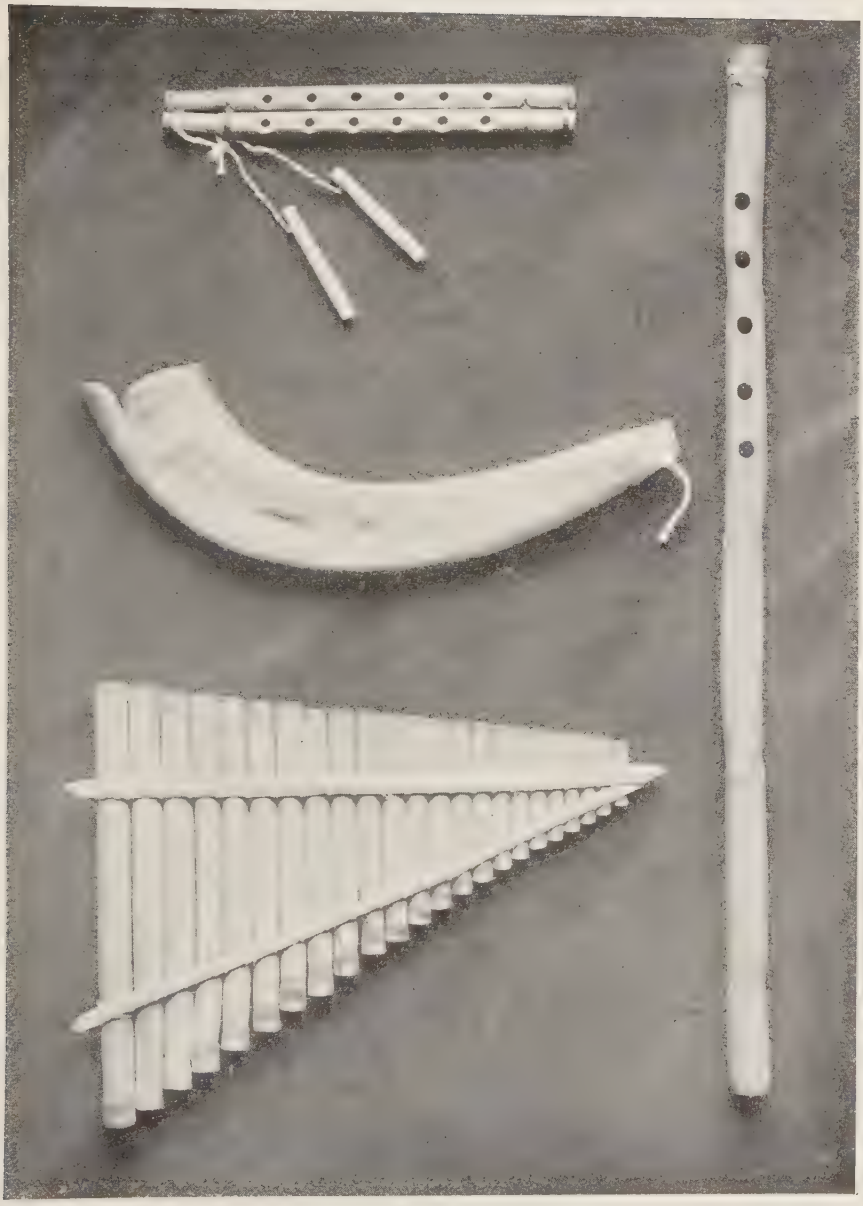
* under the Roman law de seditiosis in crucem tollendis? Digest de poenis L. 48, tit. 19. 6. 28. 3. capite plectendi cum saepius seditiose et turbulente se gesserint, et aliquotiens adprehensi clementius in eidem temeritate propositi perseveraverint?

PAGE FROM JEFFERSON'S NEW TESTAMENT.

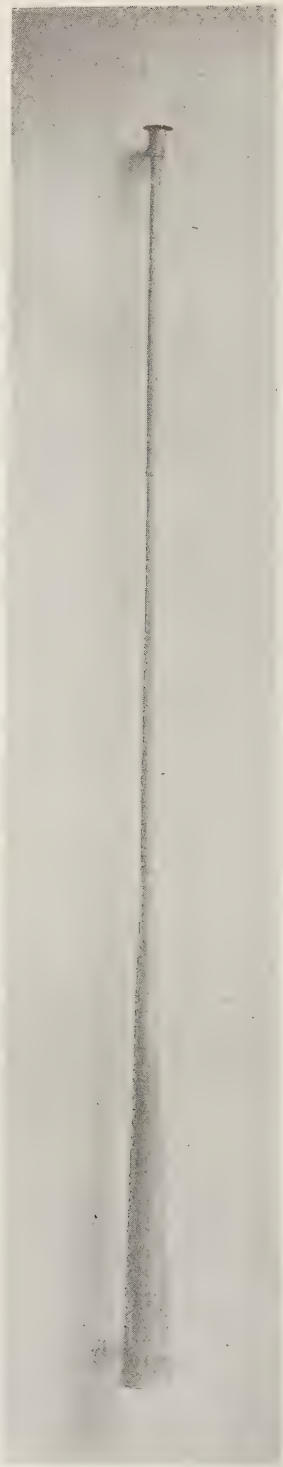

114 HIEROGLYPHICK BIBLE.
Come out from among the
s, and be ye separate,
saith the Lord, and touch not the unclean thing; and I will receive
you, and be a unto
you, and ye shall be my
and
If any of you having a
should ask his
for will he give
him a Or if he
ask a will he give
him a Or if he
shall ask an will he offer
him a to bite him?

HIEROGLYPHIC BIBLE.

MUSICAL INSTRUMENTS OF PERCUSSION



WIND INSTRUMENTS.



TRUMPET.

BAGPIPE.

SHOWING PART OF THE GRECO-ROMAN SCULPTURES.

HITTITE WINGED DIVINITY, OR DEMON, WITH HEAD OF GRIFFIN.

HITTITE LION CHASE.

HITTITE GOD OF CHASE HOLDING HARES.

THE HITTITE GOD TESHUB WITH THUNDERBOLT AND HAMMER.

HITTITE WARRIOR WITH AX AND SWORD.

HITTITE WINGED HUMAN-HEADED SPHINX.

HITTITE KING WITH SCEPTER AND SPEAR.

CORINTHIAN CAPITAL.

CASE CONTAINING GREEK AND ITALIAN POTTERY.

Beneath the lion is seen the prostrate form of a giant. Cybele is preceded by a female attendant with sword, and further to the front, by the rude and powerful form of a *Cabirus* (a deity of the subterranean fire, etc.). He carries his attribute, the hammer, which he is aiming at the most monstrous form of the whole frieze; a giant who has not only the legs of a serpent, but the hump and ears of a buffalo. He has thrown his huge bulk on his enemy, who drives his sword up to the hilt into the monster's body.

On the shelves are ranged 65 reduced casts of statues and busts representing the Greco-Roman pantheon from Zeus (Jupiter), the "Father of Gods and Men," to the shepherd god Pan with nymphs, muses, satyrs, etc. There is also among these sculptures a reduced cast of the Moses of Michelangelo, the marble original of which is in the Church of San Pietro in Vincoli, Rome, representing Moses seated, the right hand holding the Tables of the Law and clutching the long beard, while the left arm is pressed close to the body.

The cases also hold facsimiles of some of the finest Tanagra terra-cotta figurines representing Greek mythological subjects, a small collection of electrotyped Greek cameos, casts of Greek bowls (pl. 48, showing a section of the exhibit). At the end of the last case is:

A "Classical Bouquet." An album containing hand-painted illustrations of the principal monuments of Greece and a few of Crete. The illustrations are explained by appropriate quotations from the ancient Greek authors in the original language, accompanied by translations in French, and from some modern authors. To this are added flowers culled from the spots which the illustrations represent. The album was conceived and executed with the aid of native artists from Greece by Miss Elizabeth B. Contaxaki, of the Isle of Crete, as a contribution for the Universal Exposition at Paris, France, in 1855, and by her presented to the Smithsonian Institution through Mr. Charles S. Spence and the Hon. Lewis Cass, Secretary of State. Bound in blue velvet, richly embroidered in silver, with floral designs, crown, wreath, and meanders, and inclosed in a carved wooden case.

On the wall over the cases are displayed, from north to south:

(i) A selection from the Hittite reliefs (see above, p. 457) found in Senjirli, Northern Syria. They represent—

1. Two goats leaping at one another.
2. Winged divinity, or demon, with head of griffin (pl. 49).
3. Lion chase, with the winged sun disk, the emblem of divinity (pl. 50).
4. Guitar player.
5. Lion-headed god of the chase, holding hares (pl. 51).

6. The storm god Teshub (corresponding to Addad of the Assyrians and Hadad of the Syrians), holding in one uplifted hand the thunderbolt, in the other an ax or hammer (pl. 52).

7. Warrior with ax and sword (pl. 53).

8. Winged sphinx with head of griffin.

9. Warrior with shield.

10. Winged human-headed sphinx (pl. 54).

11. Figure holding mirror; and

12. King in long robe with scepter and spear (pl. 55).

(ii) Four slabs from the frieze of the Parthenon in Athens, Greece (see under No. 52).

(iii) Reliefs from Harpy Tomb at Xanthos. The originals of white marble are in the British Museum, London. The monument from which these reliefs were taken was discovered in 1838 at Xanthos, in Lycia, Asia Minor. It is assigned to the sixth century B. C., and consists of a solid rectangular block of limestone, 17 feet high and 8 feet 4 inches square, surmounted by a low cornice and a flat top. Below the cornice is a frieze, about 3 feet 3 inches in height, surrounding the four sides of the monument, leaving only a small opening on the west side, through which the remains of the dead were passed into a chamber cut in the rock. The name "Harpy Tomb" is derived from the flying figures at the corners, each of which has the head, breast, and arms of a maiden, the claws, wings, and tail of a bird, and an oval body. Each is carrying a small human figure and represents the transport of souls to the lower world.

44. In the alcove, next to the case:

Head of David by Michelangelo. Cast made from the original statue of marble in the Academia at Florence, Italy. The statue is of colossal dimensions, known as the "giant," representing David holding the sling in his left hand and a pebble in his right hand (I Samuel xvii, 40), and is considered as one of the masterpieces of Michelangelo.

On the wall, Eleusian Relief. Cast of an original of Parian marble which was found in 1859 at Eleusis, Greece, and which is considered to be a work of the fifth century B. C. Now in the National Museum of Athens. The relief represents Demeter (Ceres) and Persephone (Proserpina), goddesses of agriculture, dispatching Triptolemus, a mythical youth of Eleusis, to spread the blessings of agriculture among men. In the center stands Triptolemus, his right hand uplifted to receive some object from Persephone, whom he faces. She bears in her left hand a long scepter, the right hand probably held ears of grain which she was giving him. Behind him stands Demeter, holding in her left hand a torch and with the right she is presumably placing a wreath or crown upon his head.

Ranged on bases at the south end of the hall are some of the large sculptures.

45. "The Fates." Original, of marble, in the British Museum, London. The two female figures formed part of the decoration of the eastern pediment of the Parthenon in Athens, Greece. They are commonly interpreted to represent, with a third female figure which was seated at their head, the three Fates (in Greek, *moirai;* in Latin, *parcae*), who rule the destinies of men and all things. Their names in Greco-Roman mythology are: Clotho, the spinner of the thread of life, usually with a spindle; Lachesis, the disposer of lots, who determines its length, with a globe or scroll, on which she writes the destiny; and Atropos, the inevitable, who cuts it off, with shears or scales.

46. The Laocoon Group. Cast of an original of Greek marble, now in the Museum of the Vatican, Rome, which was found in 1506, among the ruins of the palace of Titus, on the Esquiline, Rome. The group depicts the death, during the Trojan War, of Laocoon and his two sons, as described chiefly by Virgil in the Aeneid. Pliny (Natural History, xxxvi, 5), who saw the original work in the palace of Titus, ascribes its execution to Agesander, Polydorus, and Athenodorus, Rhodian artists, who probably lived in the time of Titus (d. 80 A. D.).

47. Corinthian Capital. Cast from the capital (partly restored) of a marble column of the temple of Castor, also known as the temple of Jupiter Stator, in the Forum in Rome. This temple, of which only three columns and the base remain standing, was originally erected in 496 B. C.; rebuilt in 117 B. C.; and again rebulit under Trojan (98–117 A. D.) or Hadrian (117-138 A. D.). It is considered to have been the most beautiful example of Roman architecture, and the capitals of its columns the most finished and elegant of the Corinthian order as developed by the Romans. The basis of the capital is a cylindrical core, which expands slightly toward the top so as to become bell-shaped. Around the lower part of the core are two rows of eight conventionalized acanthus leaves, based on the plant of the *Acanthus spinosus.* From these rise eight principal stalks which combine to form four pairs of volutes, one under each corner of the abacus, while smaller stalks, branching from the first, cover the rest of the upper part of the core. Between the angle and center volutes rise tendrils from which foliage is carried along the cavetto molding of the abacus. The abacus is on the plan of a square whose sides have been hollowed out and the corners truncated. From the middle of the abacus springs out, on each face, an eight-petaled rosette.

The cast was used as a model for the carving of the capitals of the columns placed at the southern (main) entrance of the Natural History Building of the United States National Museum (pl. 56).

48. "The Falling Gladiator." Original cast of a marble statue by Dr. William Riemer (1816–1879).

49. Egyptian Lion. Original of red granite in the British Museum, London. It is inscribed with the name of Tutankhamon, a king of the eighteenth dynasty, about the middle of the 14th century B. C., who dedicated it to Amenophis III.

50. Hermes, from the Island of Andros. Cast of an original of marble now in the National Museum of Athens, Greece, found in 1833 on the Island of Andros. It probably dates from the 4th century B. C. Hermes was originally the protecting deity of crops, flocks, and roads. His usual functions were those of a messenger of Zeus and leader of souls to the lower world. He was also the god of eloquence, inventor of the lyre, and patron of merchants and craftiness. The Romans identified him with Mercury. He is here apparently represented in his quality as conductor of souls. Around the tree trunk is coiled a serpent, symbolic of the connection between the upper and the lower world, and in one of his hands he probably held the wand (*caduceus*). Other attributes with which he is frequently represented are the winged cap (*petasus*) and the winged sandals (*talaria*).

51. Ogam Stone. (Reproduction.) From Aglish, County Kerry, Ireland. The Ogam characters are on the two upright corners. They read from the top—APILOGDO and MAQIMAQA. The first is probably a proper name, while Maqi or Maqa means "the son of." The inscription is imperfect. It has been rendered Apilogdo, the son or grandson of some unnamed person, but various interpretations have been given.

Ogam characters form a written alphabet for the Gaelic language, in use in parts of Ireland, Wales, and the Highlands of Scotland during the prehistoric period and continuing into the early centuries of the Christian era. They consist of shorter or longer parallel marks on a corner or stem line made in different directions and in groups of different numbers. They can be translated into Roman letters. Marks representing consonants are from 3 to 5 inches long; those from the corner to the *left*, at right angles, and in groups of 1, 2, 3, 4, and 5 marks stand, respectively, for B, L, F, S, N; the same to the *right* stand for H, D, T, C, Q; those crossing the corner at an angle of 45 degrees, for M, G, Ng, St, R; while the vowels are shorter lines or dots, and stand for A, O, E, U, I. The cross stands for P, or the diphthong AE.

52. The Parthenon. Model of wood. The Parthenon ("maiden's chamber") was the temple of Athene Parthenos ("maiden goddess"), the tutelary divinity of the city of Athens. It was erected in the middle of the fifth century, B. C., by the architects Ictinus and Callicrates under the direction of the sculptor Phidias, and stood on the summit of the Acropolis of Athens. By reason of the perfection of its proportions and the nobility of its sculptural decorations, the Parthenon is considered the most perfect monument of Greek architecture and art. It measured at the platform 228 by 101 feet, while its height was 65 feet, and was surrounded on three sides by a Doric colonnade. It was wholly built of Pentelic marble, and all its parts were joined and adjusted without cement. On the 92 metopes of the architrave were sculptured the battle of the gods with the giants, the contests of the Greeks with the Amazons and Centaurs, and, presumably, the conquest of Troy and the victory of the Greeks over the Persians. In the two pediments (gable roofs) were colossal groups representing, respectively, the birth of Athene, and the dispute between Poseidon (Neptune) and Athene for the possession of Attica, while on the frieze, which ran around the entire building to a length of 522 feet 10 inches, was depicted, in relief, the procession which took place during the Panathenaea, the chief festival of the goddess. Inside the temple stood the statue of Athene, made of gold and ivory, ascribed to Phidias, which, with its pedestal, rose to a height of 38 feet.

After having served in turn as a Greek temple, Christian church, and Mohammedan mosque, the central part of the Parthenon was destroyed by a powder explosion during the siege of Athens by the Venetians in 1687. It remains standing as a ruin with many of its columns in place, conveying a good idea of its original proportions. Most of the sculptures from the Parthenon are now in the British Museum—the so-called Elgin marbles.

The floor space in the hall is occupied by two rows of alternating double slope-top cases with upright center (called "American," cases) and flat-top cases, one extending through the middle, the other being on the window side.

Beginning at the north end with the middle (east side) row:

53. Containing the finer and older Greek and Italian pottery (see above, p. 440), ranging from the seventh to the fourth century B. C. (pl. 57).

54. Bronzes, necklaces, and lamps from Italy.

55. Greek and Italian pottery (smaller vessels). Bronze objects used for personal ornament; Fibulae, rings, pins, mirrors, torques, bracelets, wristlets, anklets, and figurines of man and animals. Mostly from Italy and Switzerland.

The fibulae, or safety pins, occur from the earliest civilization of the Bronze Age to the latest Roman times and even later in Anglo-Saxon and Scandinavian examples. They were usually made of bronze, though in the more elaborate and ornamented forms they were sometimes of gold. They vary greatly in size, the large bronze specimens being six inches, or even more, in length. The earliest fibulae are simple safety pins made of a single wire, sharpened at one end, twisted in a spiral, or circular curve about the middle, in order to give it a spring, and at the other end so bent as to form a catch and shield for the point. To this simple pin succeeds the fibulae with an arch or bow. From this developed the boat-type, in which the bow is so curved and shaped as to resemble a boat. The shield and bow are often decorated with designs, in relief or incised, and pendants.

56. Collection of necklaces, figurines of gods, mummied hand of a woman, and mummied cat from Egypt.

57. Large bronze vessels: Amphoras, pails (situlae), bowls, pitchers. Collection of terra-cotta figurines (see above, p. 443), and Roman-Etruscan bronze domestic utensils, as pans, cups, ladles, strainers, a steelyard; also masks and stamps.

58. Collection of ancient coins, seals, and bronzes. The coins were for the most part ploughed up by the natives in the region between Antiochia and the Euphrates in Syria, while the bronze figurines were found near the site of Carchemish, the ancient capital of the Hittites, modern Jerabis on the Euphrates, Syria.

59. Small bronze and pottery vessels. Small bronzes used in the toilet and dress, as razors, strigils, buttons, awls, bodkins, and needles; also a collection of surgical instruments, mostly from Italy.

60. Relics of the Stone Age from Germany.

61. Large bronze vessels; a bronze helmet; bronze heads and statuettes; bronze celts, swords, spearheads, knives, sickles, together with the stone molds for casting various bronze implements from various localities.

The term "celt" is used in archeology to describe implements of chisel-form, such as axes, hatchets, adzes, and chisels, which were used as cutting-tools or as weapons. The word is generally derived from the Low Latin *celtis*, a chisel. The bronze celts vary in size from one inch to one foot in length. The following four principal forms are distinguished in the development of the bronze celts:

1. Flat celts, the earliest and simplest form, approximating in shape the polished stone celts of the Neolithic period. They were probably hafted by the butt end being driven into a handle of wood, in the same manner as many stone celts have been mounted.

2. Flanged celts, having projecting edges produced by beating up the edges of the blade, or in the original casting. Such axes could be fixed more firmly in a cleft stick, and to prevent the blade from being driven too far into the handle it was sometimes provided, about midway, with a rise or stop ridge.

3. Winged celts, in which the flanges are extended so as to almost form wings. In some the enlarged flanges are hammered over, so as to form a kind of semicircular socket, with the part of the celt between them thinner, thus providing a deep groove on either side of the blade for the prongs of the handle. To this variety the name of "palstave" is given, a word derived from the Icelandic. The handle was at first secured by binding and later by the addition of loops at the sides of the celt, through which a cord passed behind the angle of the haft.

4. Socketed celts. Evolved from the flanged celts when core casting was introduced. In this form the handle is imbedded in the blade, while in the first three the blade was imbedded in the handle.

62. Stone implements from East Africa (see above, p. 434).

63. Antiquities from Troy (Hissarlik) and Armenia (see above, pp. 433 and 439).

64. Stone implements from South Africa (see above, p. 435).

65. Stone implements from Egypt and Palestine (see above, pp. 434 and 433).

66. Wooden model of a Swiss lake dwelling, with a selection from the agricultural and textile products of the lake dwellers. The model is provided with a glass plate representing the water. A wash of color administered to its lower side gives it a blue tint common to the lakes of Switzerland. Figurines of men, women, and children are shown pursuing the vocations of daily life (see above, p. 422).

67. Prehistoric antiquities from Japan and Korea (see above, p. 433).

68. Stone implements from Australasia (see above, p. 435).

69. Prehistoric antiquities from India and Cambodia (see above, p. 432).

In the outer row of cases, on the west side of the hall, beginning at the north end are:

70. Italian pottery, chiefly black ware and Arretine ware (see above, p. 442).

71. Prehistoric antiquities from Turkestan (see above, p. 440).

72 and 73. Two upright or special cases, containing prehistoric antiquities, stone implements, osseous remains and bone implements,

spindle whorls, terra-cotta lamps, glassware, etc., from Italy (see above, p. 428).

74. A small collection of Jewish and Egyptian objects.

75. Stone implements and osseous material of the Paleolithic period of the Stone Age from England and Ireland (see above, p. 424).

76. Prehistoric antiquities from Russia (see above, p. 430).

77. Remains of the Neolithic period of the Stone Age in Great Britain.

78. Collection of Brandon flints (see above, p. 425).

79. Stone implements and osseous material of the Paleolithic period of the Stone Age from France (see above, p. 426).

80. Selected casts of art works of the Stone Age (see above, p. 427).

81. Remains of the Neolithic period of the Stone Age from France.

82. Mesvinian and Strepyan artifacts from Belgium (see above, p. 429).

83. Remains of the Stone Age from Belgium.

84. Collection of animal bones, charred grains, etc., from the Swiss lake dwellings (see above, p. 423).

85. Pottery, stone, bone, and horn implements from the Swiss lake dwellings.

86. Stone implements and shells from the Danish kitchen middens (see above, p. 431).

87. Stone and bone implements and osseous material from Denmark, Sweden, and Norway.

THE SHAKE RELIGION OF PUGET SOUND.

By T. T. Waterman.

[With 2 plates.]

A discussion of the Indian groups about Puget Sound would not be complete without a mention of their present form of religion. It consists of a curious sort of Christianity, with a liberal admixture of the primitive religion of this area. It is called the *Shake Religion* or *Shaker Religion*, because the believers are visited by shaking or quivering spells. Invented about 1881, this religion is still flourishing and spreading at the present time. The presence of the "shaking" phenomena demands explanation, since there are analogous elements in other religious movements. The question at once arises, as to whence they derived this practice. *Shakerism* is at present the most important fact in the life of these people.

It may well be explained that there are in America two religious groups going by the name "Shakers." One is a Christian group, small in numbers but somewhat widely distributed in the Eastern States, who are called "Shakers" for convenience, their self-chosen name being *Believers in Christ's Second Coming*. Their theology seems to be of a more or less orthodox Christian sort, the sect having originated in England in 1772. They practice dancing, however, as a religious observance, and hold to the principle of celibacy, which is followed by the entire body of believers without exception. Among converts to this form of belief there is no marrying or giving in marriage. They moreover carry out remorselessly the idea of community in property. It is obvious, I think, that doctrines such as these will not have any widespread vogue for some time to come. The fame of the group, however, and their nickname, "Shaker," has spread abroad quite widely.

Another group of people, a group many thousand miles away and of an entirely different character, has meanwhile arisen, and have also had thrust upon them the name of "Shakers." This second group is made up of the native Indians living in the region of Puget Sound. In 1881, or 1882, they invented for themselves a "new" form of religion. This system of belief has had a checkered and interesting career, and its followers now number thousands, and are organ-

ized into a "Shaker" church. There is no connection between the two organizations of Shakers, and they have nothing at all in common, except the name.

The Shaker, or "shake" religion of Puget Sound is therefore one of the world's "new" religions, in the usual sense in which religions are new. That is, it is a quaint and curious recombination of old elements.

A variety of ideas and practices may easily be recognized out of which this "new" form of belief has been patched together. The substratum back of this western Shakerism is the primitive heathenism of the Puget Sound Indians. These primitive beliefs and practices are what lend color and vitality to the whole, and result in some curious, picturesque, and wonderfully edifying performances. The history of the Shaker system is briefly this, that on the top of this old "Shamanism," or medicine-performances of the native Indian, there have been added, first, Roman Catholic ideas and institutions, and then evangelical Protestantism, derived largely from the Congregational sources. To see the various doctrines and practices derived from such origins, lying down together like the lion and the lamb in the bosom of one Redskin, is to me the most entertaining and instructive spectacle in the world.

The religion was invented and established by the Indians; but I know of more than one "white" convert. When an observer looks at this "Shakerism" he no longer feels so baffled by the quaint and heterogeneous combinations met with in the "great" religions, such as Islam, Lamaism, or Christianity. In the case of this Indian religion the combination and fusion of utterly dissimilar ideas has gone on before our eyes. I think we will have to recognize the adroitness of the Indian who combined in one ritual, elements of the Catholic mass and the Congregational prayer-meeting, to say nothing of heathen charms and incantations, older probably than either of the others.

The successful concocting of these elements was the work of one individual Indian, named John Slocum, now deceased, "our poor brother, John Slocum," as the Shaker preachers always call him in their sermons.

It is impossible not to notice that Shakerism was "in the air" among the Indians of that region, before it was invented by Slocum. Anyone who is interested in the various efforts at combining Protestantism and Catholicism by these Indians will find the facts in two entertaining works. These are *The Ghost Dance Religion*, by James Mooney (Smithsonian Institution, Bureau of American Ethnology, Fourteenth Annual Report, Part 2, Chapter 8); and Myron Eells, *Ten Years at Skokomish* (Boston, Congregational Sunday-School

and Publishing Society, 1886, especially Chapters 22–27). I know of nothing unusual about Slocum, the founder of the religion, except that he "died" in a spell of illness, and "later came to life," when they were making preparations for the funeral. This happened at a moment of crisis both in his own inner experience and in the history of his people. The combination of circumstances put the blend over, converts were made, the disciples increased and multiplied, the system expanded, and the institution is thriving and spreading to this day. The last piece of news I had concerning it was that two Apostles had gone from the Shahaptian tribe, known as the Yakima, of eastern Washington, who have had the religion for years, and had established a congregation among the Lutuami at Klamath Lake reservation in southern Oregon. The Shakers now have a bishop of their own (an Indian named Peter Heek, of Chehalis), licensed ministers, and all the paraphernalia of salvation. The religion has spread north and south many hundreds of miles from its original home.

The Catholic background of the faith may be illustrated by a brief description of the ceremonial objects which are employed. Illumination by candles is *sine qua non*. An altar covered with a white cloth is rigged up, with a cross, hand-bells, and religious pictures of Mary, the Saviour, the Sacred Heart, and so on. The principal functionaries in the ceremonies wear white cassocks. The church service consists first of a sermon, which serves to quiet everybody down and induce a feeling of solemnity. The leader then turns to one of the worshippers who stand facing him, and says, "Pray!" The member called on delivers an extemporaneous prayer which, like the sermon, is in the native Indian language. At the close of his devotions he repeats, the others following his words, in a deep chorus:

"In the name of the Father, the Son, and the Holy Ghost, it is well."

In the Nusqually dialect spoken on Puget Sound the native words are as follows, as nearly as I can write them in the ordinary symbols of English: "Tu wa′ lks nas kuma′ns tihl ta′mnas, tihl Santu Splay, tlob mas i′ sta." The term Santu Splay (Holy Ghost) is of course the French *Saint Ésprit*. This phrase (*in the name of the Father*, etc.) was the very first element of Christianity to reach the Indians of the Northwest. It came to them, passing from tribe to tribe, and was used by them as a new and powerful "medicine," long before the first missionary came to them. Every member of the Shaker congregation in turn (every convert, that is) leads in prayer or singing, or both. At the close of each petition, the well-remem-

bered chant rolls forth, "in the name of the Father," deep toned, thrilling with fervor, and a thing moving even to a neutral observer. At the end of the terminal prayer, a deacon or assistant grasps two of the bells and begins to shake them, as Indians do a rattle, one in each hand, in a pounding rhythm. The bell used by the Shakers is not the soft, tinkling bell of the Catholic ritual, silver toned and sweet in a distant chancel, but a substantial dinner bell, its note a brazen clangor that can be heard half a mile. The progress of this deacon around the premises, in a sort of crow-hop, followed in Indian file by the devotees, is accompanied therefore by a considerable din. Meanwhile, a song mounts up in time to the clang of the bells, and as each dancer passes the altar he (or she) revolves once. This exercise or parade is repeated as often as necessary or convenient. The worshippers often in going by the altar pass their hands through the flame of one of the candles, trying to purify themselves by driving away sin. At the close of the dance or parade, every worshiper shakes hands, or touches hands, with every other worshipper and with every spectator, sometimes blessing his vis-a-vis with the sign of the cross. In all these performances, rhythm is very strongly marked, the subject making many voluntary gestures, which pass in some cases into the tremor or shaking spell which has given the sect its name.

Already the curious mixture of acts, symbols, and ideas is, I think, apparent. The mixture is even more conspicuous, however, in the performances by which these people set about curing disease. The sick or ailing person (man, woman, or child) is put in a chair or a bed, and the operators gather about. A general situation appropriate for a cure is brought about by arranging candles, crosses, and religious pictures, and by singing and praying. The assumption on the part of the believers is that sickness is produced by sin, sin being something that can be bodily removed from a person by manipulation. When the patient, for example, is in the proper frame of mind, they pass their hands over his body, gradually working the sinfulness to his extremities and then gathering it in their hands and "throwing it away." The pantomime is often very clever and convincing. On occasion they may vary proceedings by passing a lighted candle along the patient's limbs, to burn away the sin. It is conspicuous that the "shaking" exercise, in its most noticeable form, usually seizes the persons who are curing the sick. I have observed some "shaking" during the course of the Sunday service in church, though a large part of the movements seemed to be voluntary, by way of inviting a shaking spell or trying to induce one. The people who treat the sick, however, very often have the shaking visitation to such a degree that they are completely lifted out of

themselves, becoming suffused with religious emotion, and ringing the bells in a perfect fury, and not seldom losing their senses. A Saturday evening meeting is often called in the church for the purpose of curing sick people, and the excitement at that time mounts much higher than it does in the Sunday services.

A good deal more might be said about the outward manifestations of this religion, but I want especially to speak of the presence in what I have already said of a primitive or shamanistic element, which has come down directly from their aboriginal life and which to me is the interesting thing in the system. The idea of "brushing off sin" from a sick person in order to effect a cure is obviously a direct survival of the old shamanistic way of curing through taking out the disease, or the "pain," as a tangible object. Especially on the northwest coast, heathen shamans always operate with rattles and dances and songs, making a furious disturbance, and finally removing the "pain" from the person with their hands. It is well known that shamans and sucking doctors, not only in this region but far and wide among the world's primitive tribes, are able to remove the pain from a patient *and show it to him afterwards;* palming some small object, such as a claw or a quartz crystal, and appearing to draw it from the tissues. On the northwest coast it has been the custom through many centuries to regard illness as due to objects or substances within the patient, usually invisible to all but the "doctor," which the medicine man is able to draw out. The pantomime used in the Shaker operations itself is probably part of this primitive style of operation.

I can not resist the inclination to cite here a passage from Swanton's *Haida Texts* (Bulletin 29 of the Bureau of American Ethnology) concerning a famous shaman called Tc!aawu'nk! This man once felt inwardly that the *land-otters* were coming to get him, to cure one of their number who was "sick." The incident which follows illustrates exactly the idea current among these Indians in former days as to the cause and cure of sickness, whether in land otters or in humans.

When he came back from this adventure he saw that the land-otter people were coming to get him. . . He told his nephews that they were coming to get him that night. . . At midnight they came by sea and got him. . . They came in and took him out. . . They got him for the son of the chief among the land-otter people who was sick. . . He took his drum. . . and they started off with him. They had him lie on his face in the bottom of the canoe. They did the same thing to his nephew. After they had gone along for some time they said that the bottom of the canoe was foul, and they landed to clean it. This meant their fur had become wet. The cleaning of the canoe was done by their twisting about. Then they got in again, put them on the bottom, and started off. After they had gone along for a while longer something touched their heads. This, they felt, was the kelp under

which the otters were diving with them. After they had gone along for a while longer they said they were near the town. . .

When he entered [the house] he saw many shamans gathered in the house. He plainly saw a bone spear on the surface of the body of the sick otter. Just before this, some persons had gone hunting from the town where Te!aawu'nk! lived. They speared a white land-otter with a spear. The creature that carried it away was sick here . . .

He began at once to act like a shaman. After he had danced around the fire for a while he pulled out the spear, and the sick otter stopped moaning. After he had acted for a while he pushed it back into the same place. . . After he had danced around the fire a while, he pulled out the spear. He pushed it in again. He pulled it out, and stopped performing. He put it in again, and the otter began again to suffer. He now performed again, and he pulled out the spear for the last time. The chief's son was saved.

The corresponding performance of our own people has been briefly described by Eells (Smithsonian Report for 1887):

There were two fires. . . and the doctor was between them on his knees on the gravel. He was stripped to the waist, having only pantaloons and boots on, and faced the woman. He had a small tub of water. . . He worked up to the woman and, as near as I could see, placed his mouth on her chest or shoulders and sucked very strongly and then blew out of his mouth with all his force, making a great noise, sometimes blowing into the air, always remaining on his knees.

On another occasion the "doctor" put his hands in water, having warmed them a little, and then placed them on the woman's side, her dress having been opened and partly taken down for the purpose, and he acted as if he were trying to draw out something. This was done a second time, when he plunged into water, placed his mouth next to them and blew suddenly and powerfully a few times * * *.

It is perfectly plain, I think, where the Shaker idea of curing sickness by *taking something away from the patient* took its origin. The "Shaker" apostles were in fact called "*blowers*," or Shäpupu-'lema by the Yakima east of the Cascades, evidently because they utilized the type of performance just described. The notion that it is sin which is to be removed is of course an infiltration into the Indian's point of view of Christian preachments.

It is noteworthy that in the very region on Puget Sound in which the Shaker religion evolved, the principal religious performance, which is known as the "Spirit Canoe" or Sbɛtɛtda'q ceremonial, was a tribal observance whose purpose was *to heal the sick*. This has been described by Haeberlin in the American Anthropologist (n. s. vol. 20) and by Dorsey in the Bulletin of the Free Museum of the University of Pennsylvania (vol. 3). The existence of this old healing ceremonial accounts, I think, for the religious fervor that attends the healing of the sick by the Shakers. It is an old tribal tradition with them that treating the sick is a proper occasion for

religious fervor, the best and most appropriate occasion for spiritual manifestations. The details of the old "Spirit Canoe" performance do not matter for our present purpose. It is, however, a very picturesque and wonderful ceremonial indeed, and the point was brought conspicuously to my attention that for generations there have been "shaking" phenomena connected with the performances.

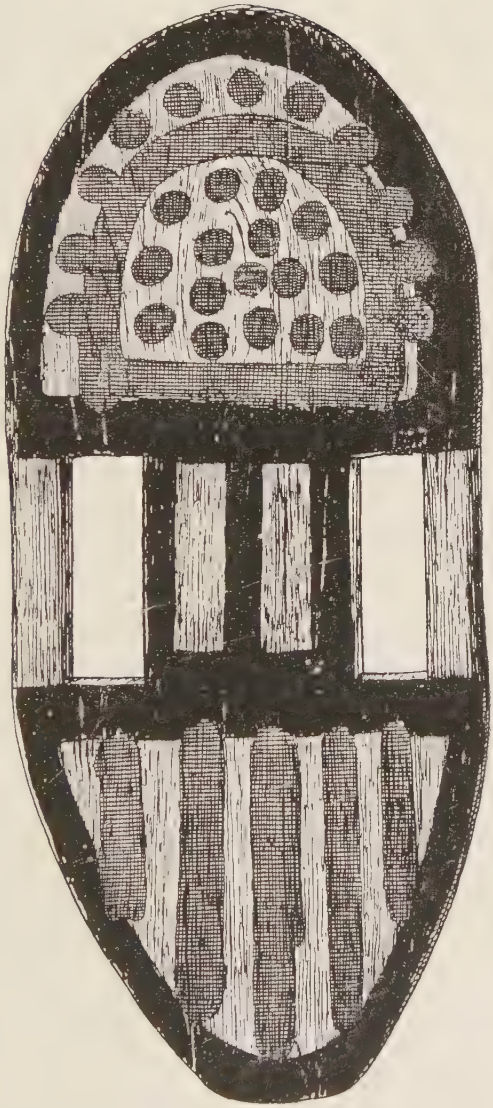
The principal part of this performance, for example, was a scene, acted out in pantomine, where certain medicine men went to the underworld to recover the "soul" of a sick man taken there by the "ghosts." The shamans went (in imagination) on a long journey, to the village of the dead people. When they got there and began prowling around among the houses looking for the missing soul the sick man always fell into an ague. When the soul was found and brought back to this world, the next problem was to *put it into the patient again.* They brought it "from below" in a cloth, gathered around the patient, and made motions as if putting it into him. If it started to float away they would seize it and bring it back. Finally it would take fast hold and the patient was forthwith pronounced cured. During this process the shamans would shake and tremble in every limb. Here we see, therefore, in ancient times, almost the exact counterpart of the modern Shaker exercise; the patient helpless, with the operators gathered around him all shaking and quivering. Nowadays they are, of course, trying to get the sin *out*, instead of putting a soul *in.* The ideas have shifted, but the performance remains the same.

I may illustrate this point further by saying that in the old days there were several spirit-powers, the possession of which was accompanied by a similar shaking seizure. For example, there were also in use certain long cedar poles, called *te' stid* which musicians up-ended and used for drumming against the roof-boards of the house, as an accompaniment to the songs. Certain people possessed a kind of supernatural power or "spirit-help" known as Tsotsotob. A man who had this power could announce, "Now my power will come into those drumming poles." Then the poles would begin of themselves to quiver, so that the man holding them was thrown into a tremble. Another "power" was called *skudi'litc.* People who "owned" this spirit, made objects of cedar, like a board, as shown in plate 1, figure 2, with hand-holds at the sides. These objects were held in the hands of the performers, and very often "power" entered them, causing them to quiver and move about. This likewise threw the person holding them into a tremor. A certain skudi'litc-object like the one shown in the sketch once moved all about a room, the performer trembling and unable to remain in his place. It dragged him through the fire; it dragged him out of

the house. With all his might he held back, straining and resisting, and finally two white men came to his assistance; but it dragged all three into the river! Specimens of these objects are in the Museum of the American Indian, Heye Foundation, in New York City, and in certain other of the great museums. There is not the slightest doubt but that the quivering and shaking manifested in connection with them goes back a considerable distance into the days before the white occupation. The Indians say that the wooden object became "possessed" and shook the performer, while we would, of course, assume that the performer fell into a shaking seizure, such as occurs in many religious exercises among other races and in other parts of the world, his shaking agitating, in turn, the object he carried. It seems to me that in these old performances and these ancient objects we have the background upon which the present day motor disturbances developed, which give the Shaker group its name. I know educated Indians who have seen these old spirit-objects come to life, and cause the person holding them to tremble like a leaf.

One other point occurs to me in connection with this Shaker religion, which makes one think of the story of some of the world's great religions. I spoke above of "Shaker" organizations, with church buildings, which have now spread among the Yakima and the Lutuami, and other tribes far removed from Puget Sound. John Slocum had his "inspiration," the religion started, and the first meetings were held on the shore of one of the numerous inlets of Puget Sound called "Big Skookum," not far from Olympia. On the north side of that inlet, where the water races by at a change of the tide, is where Slocum lived and "died" and came back to earth from the heavenly regions with a message for his people. It was the Indians there who got his message first, and began to shake, and organized the church. These very Indians, however, have now stopped shaking. They no longer have any particular faith in "shake-help," and have ceased to hold meetings. The very people among whom the movement started were therefore the first to fall away. This makes one think of the curious history of Christianity, a religious system originating in western *Asia* but associated in its later history with *Europe*. Asia has never been Christian in any considerable part since the early days of Christian history. The case of Buddhism is also in line; Buddhism being, of course, a product of Hindustan, originating there, and being borne afar from that country as a center. But only for a relatively short time was Buddhism actually associated with the land of its birth. Buddhists are nowadays to be found by millions in China, in Japan, in Burma, in Siam, in Cambodia, in Tibet; but in the valley where it started

1. POLE FOR DRUMMING ON THE ROOF BOARDS.



2. A SKUDI'LITC OR CEREMONIAL OBJECT OF CEDAR WOOD, WHICH IS HELD IN THE PERFORMER'S HANDS. AT TIMES IT BECOMES FILLED WITH "POWER" ACCORDING TO THE BELIEF, AND MAKES HIM QUIVER AND MAY EVEN DRAG HIM ABOUT. THE DOTS REPRESENT THE SONGS REVEALED TO THE INDIVIDUAL BY THE SPIRITS.

Courtesy Museum of American Indian, Heye Foundation.

A GROUP OF THE PUGET SOUND "SHAKERS" AT TOLT, WASH., GIVING A "BLESSING."

not one Buddhist is to be seen, save perhaps pilgrims, two or three in a year. Thus the history of two of the world's greatest religions is reproduced in miniature among the simple Indians of our own Northwest.

The shaking which thus appears in both the old and the new religions of Puget Sound has been explained psychologically. I do not recall the details, but it is something about nervous tension and rhythmic discharges, resulting in one movement repeated over and over again until it becomes a tremor. I have remarked already that it is by no means new in the study of religion; quite the contrary. Various saints, dervishes, marabouts, diviners, deacons, and elders in various religious exercises and of various races show it. The Tarantism of the Middle Ages (Saint Vitus's dance) was evidently something of the same sort. I can do no better, I think, than to quote a passage from Davenport's Primitive Traits in Religious Revivals, describing what happened to our own civilized mountaineers in the Cumberland region in 1842; the place, I believe, where the Cumberland Presbyterian Church took its origin. He gives on page 78 of his work an account of the following quaint and curious behavior:

> Next to the "falling" exercise, the most notable and characteristic Kentucky performance was the "jerks." The unhappy victim shook in every joint. Sometimes the head was thrown from side to side with great rapidity. . . . Peter Cartwright declared that he had seen more than five hundred persons jerking at once in his congregation. And Lorenzo Dow, writing of a time some years later, when the epidemic again broke out in this section, remarks that on Sunday at Knoxville, the governor being present, about one hundred and fifty had the jerking exercise. In 1800 no one was proof against it, saint or sinner, white or black, except, as Lorenzo Dow naively remarks, those who wished to get it to philosophize upon it and the most godly.

One final word about these Shakers will not be out of place. The Congregationalists and Presbyterians, under whose influence they fell, took a strong stand against drinking, gambling, horse-racing, lying, swearing, and smoking tobacco. Whatever may be said about the relative rank of these failings, certain it is that to the Shakers avoidance of them is an essential part of religion. No Shaker will swear, no Shaker will drink. The one virtue of non-indulgence in alcohol has served to make the members of the Shaker church the most prosperous of the Indians. Outwardly their homes are clean and cheerful and inwardly they are filled with a kindly feeling, which can not be mistaken, for it actually radiates from their faces. It makes them, to my way of thinking, more closely resemble the Christian of our ideals than is the case with any people I have ever seen, Indian, white, or otherwise.

ASKALON
WELL
BAB GAZA
BAB YAFA
BAB EL QUDS
WALLS
PRE ROMAN
ROMAN
BYZANTINE
ARAB
CRUSADER
MODERN
Scale : Metres

THE EXCAVATIONS AT ASKALON.[1]

By Prof. J. Garstang, D. Sc.

[With 3 plates.]

Introductory Note.

Askalon (Hebrew Ashkelon) was one of five cities of the Philistines on the southern coast of Palestine, 30 miles southwest of Jerusalem (Joshua xiii, 3; i Samuel vi, 17). In Egyptian texts it occurs as Askarumi among the cities revolting against Rameses II and Mereptah, while in Assyrian inscriptions it is frequently mentioned under the name of Iskaluna or Askaluna. Askalon was the center of the worship of the fish goddess Derketo, to whom fishes were sacred. Herod, who, according to tradition, was born in Askalon, adorned it with baths, fountains, and public buildings. But the most flourishing period which Askalon experienced was under Roman control, when it became a center of Hellenic culture. Under the Arabs, who called it "the bride of Syria," Askalon was a frequent object of struggle. It was taken during the Crusades by the Christians in 1154, retaken by Saladin in 1187, dismantled and then rebuilt by Richard Coeur de Leon in 1192, and finally demolished in 1270. It is now represented by the village of Askalan.

The object of this brief report is to give a résumé of the work done and the results obtained during the two seasons of excavation at Askalon, 1921–22, without entering into a discussion of detail or of theories. Further evidence, both direct and comparative, will be forthcoming, it is to be anticipated, as a result of the present year's work now about to commence, so that the fuller discussion can only be profitably undertaken at a later stage, after maturer study, with all the facts in view.

The work done resolves itself readily into three parts:

I. General survey and exploration of the site.

II. Excavation of the area and substructures of the public building now revealed as Herod's Cloisters (formerly called shortly the "Tycheion"), with the adjacent "Basilica" and the later theater and mosque.

III. Search for traces of the Philistines and other early settlers.

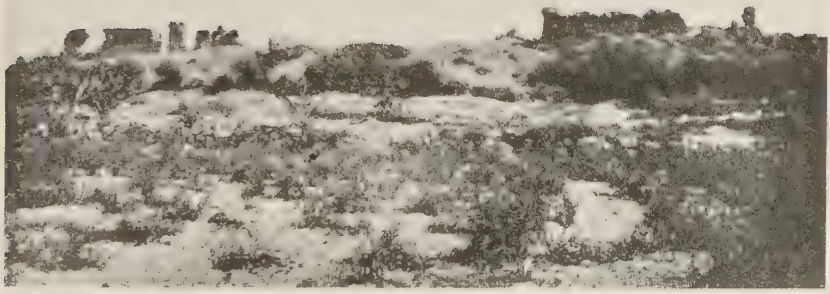
[1] Reprinted by permission from Quarterly Statement of the Palestine Exploration Fund, July, 1922.

I. The general survey began with the preparation of a surface chart to a scale of 1:2000, here reproduced for ready reference from the Quarterly Statement of April, 1921, on a scale of about 1:5000. Plans of visible and excavated buildings are being prepared to a scale of 1:200, and details to 1:100. The visible superficial remains include the great rampart of semicircular form abutting upon the sea, crowned with mediæval masoned walls, in which there are evident traces of repair and destruction consistent with the Chronicles of the Crusades. The date of the underlying earthen ramparts has not yet been ascertained. They seem to be much older, and may well belong to the period of the migrations which brought the Philistines or to the Hyksos Period. (Pl. 2, fig. 1.)

The inclosure, with its ramparts of beaten earth, is indeed comparable with the great camps of more regular form which have been indicated at Tell el-Yahudieh on the Egyptian frontier, near Homs in Syria, and further east in the Merv Oasis, Turkestan. The camp near Homs was associated in some way with the Hittites, and the ramparts defending the southern approaches to the Hittite capital at Boghaz Keui in Asia Minor are of similar appearance and character, though they have been reinforced at some date by a revetment of stone.

The knoll rising by the sea within this area was apparently the oldest and the most defensible portion of the inclosure from the beginning down at any rate to early Roman times. While we have not yet traced the foundations of the citadel such as Rameses II assailed—according to contemporary Egyptian pictures—there can remain little doubt that it crowned this knoll, and that the development of the city was by marked stages of expansion, of which the terraces roughly perpetuate the outline, until in Hellenistic times it inclosed the whole knoll. Thereafter, with the rapid prosperity heralded by the Roman freedom, it spread out over the more level ground within the broad circuit of the ramparts and over the northern knoll as well. For this reason there is nothing visible upon the surface of pre-Roman date; but of this and later periods there are abundant traces. Nearly every field contains fragments of columns or bases or capitals, and the nature and date of the various buildings can be sometimes guessed from the distribution of these remains. There is a fine group of granite columns lying at the junction of the cross roads (field 151). Local accounts indicate that they belonged to the "temple of Jupiter" which was revealed last century.

The site of the Bir Ibrahîm, the Well of Abraham, spoken of by many writers from Origen and Eusebius, is practically certain, and



1. ASKALON: GENERAL VIEW OF THE RAMPARTS.

2. CORINTHIAN CAPITAL.

BIR IBRAHIM. THE COMMENCEMENT OF THE EXCAVATIONS.

it is indicated in the Plan by the circular depression No. 88 (pl. 3) in field 80. Here we have examined the surface, but the remains are fragmentary and clearly of mediæval date. At this age, our authority states, broad steps descended to a chamber, and on all four sides of this chamber were springs of water gushing out from stone conduits. Excavations in field 61 have shown that as early as Hellenistic times the Well of Ibrahîm was an important focus of interest in the town, for an avenue of columns has been found heading directly toward it. The suggestion is still preserved by the modern lane at this point. It is in fact interesting to speculate how possibly it perpetuates the memory and part of the site of the more ancient Sacred Lake, which was still extant at the time of Diodorus Siculus.

The apsidal Byzantine church in fields 5, 24 (described in the Quarterly Statement for January, 1921), and the remains of Crusaders' buildings in field 86 and at point IX (on the northern knoll) are the most conspicuous surface landmarks within the ramparts. Four small columns are still standing, apparently as they were placed, near survey point VII inside the eastern wall, south of the Bab el-Kuds (or Jerusalem Gate); doubtless they indicate a small church of Crusaders' date, but the excavation has not yet reached this spot. The exploration of the site as a whole, for a kilometer at least beyond the radius of the ramparts, has been pursued continuously in search of traces of early interments which would have thrown light swiftly upon the object of our quest. But while tombs of Roman date are plentiful and those of Hellenistic age (*c.* 300 B. C.) not uncommon, no trace has been found of any burials—whether by cremation or by inhumation—of an earlier date, except upon the central knoll. It can only be inferred—subject to further results—that the burials of Philistine and earlier date took place in the ground outside the central acropolis since occupied by the Roman city and hence most difficult of access.

It only remains to say, as regards the site as a whole, that numerous soundings have been made and trenches cut, here, there and everywhere, to ascertain the broad outline of topographical development as described above. The site is large, as the map shows, and it has not yet been possible in all cases to synthesize the results.

II. *Fields 61, 67, and 52.*—In this area, as already indicated (Quarterly Statement, January, 1921), there were indications of an important public building, evidenced by the architectural caryatid statues adorned with the mural crown, and by the foundations partly

excavated in 1921. There was already the suggestion of a theater, constructed upon the outline of an apsidal building, and of the Well of Peace, which it inclosed, as described by Antoninus Martyr.

Consequently the excavation of this building has been continued to its full extent both north and south. The stoutly built apse of a basilica or "Curia" in the south of field 61, seems to have been the main feature of early Roman date. To this Herod the Great added sumptuous marble colonnades and cloisters as a sort of forecourt and main entrance. The whole overlay and completely replaced the previous avenue of columns heading for the Bir Ibrahîm. When the apsidal basilica was ruined, at any rate on or about the fourth or fifth century, its form suggested the convenient hemispherical foundation for a theater which was then constructed. The fallen statue of Peace, which with the great statue of Victory Over the World had flanked the entrance to the Basilica, and the presence of a well, gave rise perhaps to the account which Antoninus Martyr recorded in the sixth century of a Well of Peace surrounded by steps in the form of a theater. But it is possible to suppose that he was referring to the Well of Abraham, and that the identification or the description has become confused. After the theater had been razed the still rounded contour suggested to the new Arab population the *mihrab* for their great mosque. A close study of the floor levels and constructive changes over the whole area seems to indicate that the last stage saw one of the famous mosques of Askalon rising upon this historic position. Probably, as will be seen from the quotations below, it was called the Mosque of Omar.

When using the term "basilica" in connection with this apsidal structure and Herod's Cloisters it should be observed that a close study of the evidence and comparison with other buildings of similar kind, like those of Samaria and Gerasa, may make it possible to advance our results a step further and to identify the original apsidal structure as the "Bouleuterion" or meeting place of the senate, corresponding to the council chamber of our own cities. Herod's Cloisters would form the decorative approach, the whole arrangement corresponding to classical precedent such as Vetruvius and others described. The "Bouleuterion" normally adjoined the agora. The preservation of the tiers of seats in the reconstruction of the apse bears out this interpretation, which seems to be confirmed by the discovery of the tablets recording decisions of the senate or *boulè* in the adjoining cloister. (Palestine Exploration Fund, Quarterly Statement for January, 1922.)

The apse of a basilica (by which was meant the exchange and lawcourt) was in fact usually inclosed in the architectural area, and the whole was roofed. The design in the present case shows an

open court added as a decorative approach and inclosing an agora in the front of the council chamber. It remains for further investigation to show whether this identification is borne out in detail.

The following references (gleaned from Mr. Phythian Adams, History of Askalon, Quarterly Statement, April, 1921) will now be read in their full significance:

Josephus, *c.* 20 B. C. "For the people of Askalon Herod built * * * colonnades that were admirable for their workmanship and size."

Antoninus, A. D. 560. "* * * A Well of Peace, built after the manner of a theater, in which you descend by steps actually to the water."

Biladhûri, A. D. 685. "The Greeks raided and destroyed Askalon and its mosque. The Caliph Abd el-Melik rebuilt the city, fortified it, and rebuilt the mosque also."

Mukaddasi, A. D. 985. "The Great Mosque stands in the Market of the Clothes Merchants and is paved throughout with marble."

Nasis, A. D. 1049. "An Arch that was ancient * * * and had been part of a mosque * * * built of mighty stones."

Ibn Batûtah, A. D. 1355. "A beautiful mosque at Askalon, built by one of the Caliphs as the inscription over the gate still shows. To the south of this is a large mosque called the Mosque of Omar, of which nothing now remains but its walls; *but there are many fine marble columns, some standing and some fallen down.* To the south of Askalon are the Wells of Abraham. You descend to these by broad steps leading to a chamber. On all four sides of the chamber are springs of water gushing out from the stone conduits."

It remains to add a description of Herod's marble cloisters, already famous, as we have seen, in their day, and later the substructure and foundations apparently of the Mosque of Omar. The length of the colonnade was 87 meters. The cloister was about 5 meters in width, so that the whole building was more than 90 meters or 100 yards long in exterior measurement. The columns were 76 cms. in diameter; the bases were of Attic design well proportioned, and the capitals were Corinthian, of fine 1st century style and workmanship. Each column was raised, after the Syrian style of the period, on its separate pedestal, giving a total height of about 11 diameters. There is room for 32 columns on each wing and eight such at each face. The material was a white-grey marble, probably Greek in origin: some of the special columns were veined. (Pl. 2, fig. 2.) The main entrance to the north seems to have been open. That to the south led directly into the apse of the Senate House between the pair of fine statues, Peace and Victory, standing upon the World, borne on the shoulders of Atlas. There appears to have

been a similar entrance in the middle of each side. The walls were lined with marble and alabaster, with tracery windows, and occasional niches and shrines of the same material; in these were statues and statuettes and commemorative inscriptions. Portions of a giant statue, presumed to be that of Herod, another of Apollo, and fragments of others have been recovered. More beautiful are a small statutette of a kneeling Venus (like the prototype now in the Louvre) and one of a draped woman leaning sideways and backwards, supporting possibly some weight. Numerous other fragments of sculpture and decorative art have been recovered and remain for study. It may be added that the fragments of Arab faience found over the surface of this area prove to include some of the earliest and most valuable examples of that art.

The last stages in the history of this historical spot are sad to relate. The Crusaders made use of the columns, bases, and capitals to build their fortified walls, and later the Turks used Askalon as a stone quarry. The signs of vandalism are only too apparent—traces of the saw that cut up statues and pedestals for marble slabs, or, worse, to burn for lime. This wanton destruction had been going on for generations down to living memory, so that what remains is only a fractional indication of one of the really great monuments of antiquity.

III. *The Search for the Philistines.*—Reference has already been made to the search for Philistine tombs or interments in the areas around the ramparts, and the difficulty of penetrating to the Philistine levels between the acropolis and the ramparts has become now self-evident. In field 177 a determined effort was made, however, to cut down (somewhat ruthlessly) through the foundations of Arab, Byzantine, and Roman buildings, to the underlying levels, in the hope of disclosing some architectural remains of the Philistine Period. In this respect, however, the result was disappointing, and the effort showed plainly that this method of "frontal attack" within the walls of Askalon would prove in any case less satisfactory and probably less fruitful than some more studied plan. The great trench of 40 meters by 10 was dug, narrowing as it descended to a depth of 8 meters—as deeply as was safe—only to arrive with great difficulty at the pre-Hellenistic stratum. The making and remaking of foundations had also so disturbed the stratifications that evidence of position derived from this section could not be relied on without comparison. In other positions, however, very successful cuttings have been made in the face of the mound, giving reliable stratifications. That on the northern scarp in field 163 which Mr. Phythian Adams supervised in 1920 has already been described by him in the Quarterly Statement, Oct., 1921. It gave a clear picture of the superposition and cleavage of the several and successive great

periods, notably the pre-Philistine, the Philistine, the Hellenistic, the Graeco-Roman, Byzantine, and Arab. Having been able by direct evidence to recognize these levels, the fragments of pottery and other objects found in them became the first criteria by which to test and establish results of other similar soundings. Thus armed, we cut down half of the field numbered 19, which fronts the sea, to the bottom, nearly to sea level. This cutting was done with deliberation and method, and was again entrusted to Mr. Phythian Adams, who is still studying the results in the light of previous and other evidence. He will in due course publish his detailed report and scientific conclusions. Broadly it may be said that the affinities to the pre-Philistine settlers are recognizable, with a distribution centering (upon present evidence) in Cyprus and ranging through Syria as far as Egypt. The Philistine affinities are, however, unknown. The distinctive pottery fragments, &c., are numerous and are carefully noted for future reference. They are not of a known Egyptian character, nor are they Cypriote or Hittite or Cretan. They are in some ways similar in general character to sub-Mycenaean or Late Minoan wares (Class L. M., III *b*), but this resemblance only confirms their date. The finger of probability must point to some unexplored spot in the Northeastern Mediterranean, presumably upon or near the coast of Asia Minor for their source or inspiration, some spot which the culture of the Aegean would affect but did not dominate.

In this absence of comparative material—which was in fact to have been anticipated—no certain conclusion can as yet be indicated. When one considers, moreover, the records of the great migration which heralded the arrival of the Philistines upon the threshold of Egypt in the reign of Rameses III, and takes into account the episodes of the movement, the long, struggling, adventurous journey around the coast, it would not be surprising to find little or nothing in the earliest strata of Philistine occupation to represent the culture of their homeland, unless it were their arms which they would not relinquish and which were not subject to ordinary accidents. It is the contact reestablished after settlement, and the coming of fresh settlers of their kind, that would leave more common traces. Consequently it is possible that our earliest material is not the most distinctive. If, however, tombs of the early Philistines can be found with some good examples of their armour, we shall add greatly to the essential element of our evidence. We can also proceed at once to determine by soundings the area of Philistine occupation in successive centuries as indicated by the distribution of their remains already identified, and in the course of this investigation over a more extended field we may hope for some new material

clues which may be recognized and followed up with increasing prospect of success.

NOTE.—The above careful report of the expert in charge of excavating the important seaport of Askalon is suggestive of the thoroughgoing work carried on by the oldest society doing field work in Palestine. In spite of annoying changes in local conditions in the East, costs, and disappointments, the Fund continues digging the ground and publishing results which are important for Christian and Jewish students of the Sacred Scriptures.

The Palestine Exploration Fund has an American office at 8 College Lane, Haverford, Pennsylvania.

NATIONAL EFFORTS AT HOME MAKING.

By F. H. Newell,
Consulting Engineer, Reclamation Service.

[With 10 plates.]

The home is the foundation of all that is best in the State. Its preservation and the perpetuation of its ideals are duties for the Nation; there can be none higher than to furnish opportunities for homes for self-reliant citizens, particularly those of the pioneer type, whose past achievements stand out on the pages of American history. Even yet the pioneer period has not wholly passed; the pioneers are the people who are putting to use the undeveloped natural resources; they are making farms and homes in areas which otherwise would be waste and desolate. Modern science is helping these pioneers; it is extending their opportunities and lightening their labors. Notable in this connection, affording one of the best examples of scientific investigation followed by practical application of the results, are the works designed and built by the Reclamation Service. These, while in part monumental in character, are only a means to an end; that end is the creation of opportunities for small, self-supporting farm homes such as will add to the strength of the Nation.

This ideal, namely that the Nation, to insure its own life, should provide opportunities for homes for its citizens, is by no means new. It is as old as history, so far at least as it pertains to the settlement of soldier citizens, particularly following wars of conquest. It has been adopted by the United States as a part of its policy in the disposal of public lands. After the Civil War in particular the Nation encouraged the settlement of the men, who had preserved its life, on the vast extent of vacant plow lands beyond the Mississippi. Such lands, readily tillable, have now disappeared. They have all been taken up, but there remain millions of acres of unused lands which have good soil, much of it still in public ownership and open to entry and settlement. Some obstacle—either lack of water, or excess of it—is preventing the continuation of home making on these lands.

As illustrating the extent and location of these remaining vacant public lands, the accompanying plate 1 is given. On this the vacant land, aggregating 189,000,000 acres, is indicated by the solid black spots. It is only a few years ago when a similar map would have shown these black areas covering three-fourths of the country west of the Mississippi. Large portions of these vacant lands, particularly those which embrace the high mountain areas, in all 132,000,000 acres, have been withdrawn from entry and converted into national forests, smaller areas, or 5,800,000 acres, have been desig-

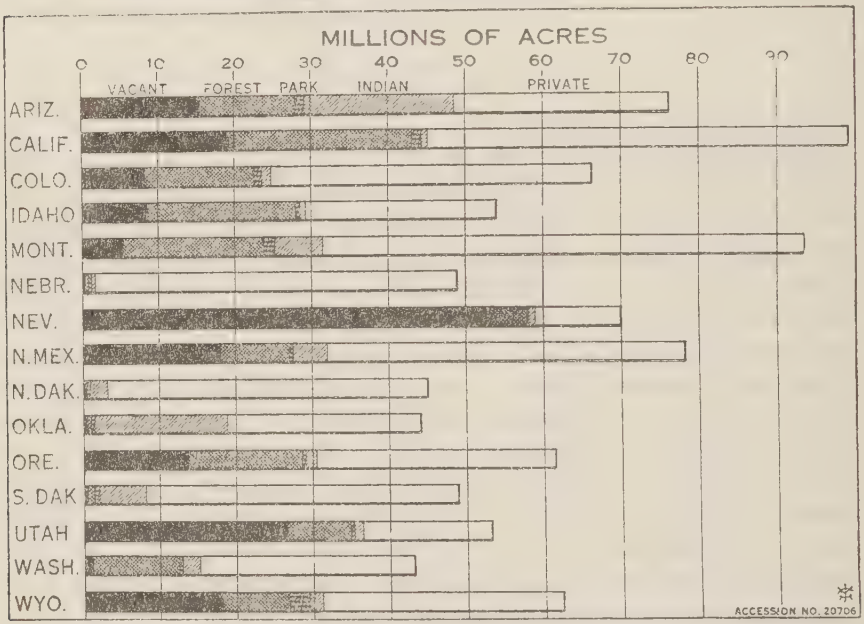


FIG. 1.—Relative area of each of the Western States; also the area of vacant public lands (in solid black); of national forests (in crosshatch); of national parks (in crossbar); Indian reservations (in diagonal); and in white the remainder of the State—this being in private or corporate ownership.

nated as national parks, and some parts have been reclaimed by irrigation. The relative extent of vacant and reserved land is shown in figure 1.

The nation is calling science and engineering to its aid in improving portions of these vacant or waste lands, so that the areas having fertile soil may be utilized in providing opportunities for homes similar to those enjoyed in the past in the great Mississippi Valley, where nature has so lavishly provided the easily tilled farming lands.

The conception that not merely the vacant lands of the nation, but also its funds should be utilized in providing opportunities for

homes was early championed by Theodore Roosevelt. At his earnest solicitation these ideals were embodied in a reclamation act, signed by him on June 17, 1902. This was a vital part of his conservation policy. It was closely joined to forest protection and use; it linked up with his broad conception of conservation in its wider aspects, including the health and life of the people.

Twenty years have elapsed since the reclamation act was signed—years crowded with events which have modified somewhat the attitude of the thinking men of the country toward many of the factors of home making. Population, industry, and wealth have increased in the cities, and in proportion the number of rural homes has correspondingly decreased, yet there is still insistent demand for opportunities for homes in the country. With the shift of population in the opposite direction, these needs for rural homes have become still more important.

The policy of home making, made so prominent by Roosevelt, still maintains its place in popular esteem, despite the fact that during 1921 and 1922 there prevailed a sentiment that agriculture as an industry had been somewhat overdone, that the area of cultivated land should be limited and the number of farmers reduced. These two conceptions of too much agriculture as a business and too few farm homes are not incompatible. It is quite possible to regard agriculture from a purely money-making or industrial standpoint, and to decree that the less profitable areas should be abandoned and the less successful farmers go into some other occupation. Nevertheless, when farming is considered as a mode of life—one which is primarily for the production of man rather than of money—there are strong reasons for encouraging it, notably in the remoter parts of the country where the population is sparse, and where, by the application of scientific research, comfortable and prosperous homes may be created in what was once a wilderness—particularly if these homes can be made available to the rehabilitated ex-service men, who may find a home, under a new enviroment, similar to that shown on plate 2, figure 1. Here is a beginning of one of these homes, typical of thousands of others. It requires little argument to convince the observer that the young man who has served his country, and who, after restoration to health, is able to procure and develop a home like this becomes one of the best of stabilizing influences in governmental affairs.

The rapid changes which take place in a new farm of this kind are shown on plate 2, figure 2, where there is given a view of a small farm home, taken six years after the desert was watered. Here the small, but comfortable house is shown, overshadowed by the tree growth which has been made possible by the water-supply com-

ing from the distant reservoir. With abundant sunshine and plenty of water, the previously barren landscape is transformed.

There is a decided advantage in establishing new or pioneer homes in an unpopulated or sparsely settled area, such as that reclaimed from the desert. In such a new country it is necessary to experiment and to adopt new methods of farming and of home making, devised to meet new conditions, but, as an offset to these disadvantages, it is not necessary to pull down old institutions, to overcome rooted prejudices, and to unlearn many things which have been obstacles to success in older countries. There is no undertaking more difficult, in connection with settlement and home making, than to try to locate successfully new people in an old, partly settled community where discouragement has prevailed. There the infiltering population is discouraged by the tales of woe of the "oldest inhabitants." The true melting pot of Americanism is found in the newly reclaimed or cultivated lands where all men are beginners and all are forced to work with a certain degree of equality, and where health, strength, and ability count for more than previous social position.

The works by which the country has been transformed and conditions which have been created making possible these homes for newcomers have been frequently pictured. The great reservoirs, canals, and various structures of the Reclamation Service are fairly well known, but the really important things from the standpoint of home making and its bearing upon political geography and upon the Nation's life have not been as well described.

It is generally agreed that the visible works have been built with a high degree of skill and economy. The important point to be considered is therefore as to whether or not these expensive works are being fully utilized in the production of opportunities for useful citizens. Unless this result has been attained, the works, no matter how picturesque, fail of their object. It is therefore of interest to all citizens to ascertain at the expiration of 20 years of effort something as to the real conditions of homes and of the people, and also of the reclaimed land itself, pointing out to what degree the results of scientific research have actually been made available for the benefit of mankind.

There is no doubt but that great benefits have come to the State and Nation as the result of the expenditures made; nor can there be any question as to the rapidity of the transformation of the West, or desert country, when after a decade of effort there are brought about visible results greater than those attained by generations of men in older countries. This rapid change is illustrated by plate 3. The upper portion of plate 3, figure 1, shows a vast extent of vacant public land in the condition in which it has remained for thousands of years. Immediately below this is a view (pl. 3, fig. 2) of the

same kind of land converted into cultivated fields, changed almost overnight by the bringing in of water. This desert land, which in its original condition was valueless, has been made highly productive to a point where 20 or 40 acres are adequate for the support of a family.

The present physical conditions may be summed up in the statement that at the end of 1922 about 1,200,000 acres of reclaimed land had been cropped, with a gross crop value for that year of over $50,000,000. In addition to this, several millions of dollars were returned to the farmers through the sale of dairy products, live stock, pigs, and poultry. The total value of the crop raised on the reclaimed lands since the Government reclamation began, not counting the products from older areas, to which surplus water has been furnished from storage reservoirs, amounted to over $500,000,000. This gross crop return has come from an expenditure, in round numbers, of about $130,000,000, of which one-tenth has come back to be used over again and of which all will come back in time.

The most valuable results, however, are not measured in terms of money but in the homes produced, such, for example, as are illustrated on plate 4 in figure 1, on which is shown the waste land to which the house timbers have been hauled. Below this (pl. 4, fig. 2) is a view after the land has been transformed, the small house erected, and the young orchard started in vigorous growth. In a few years it will be impossible to see the building because of the rapid growth of the trees.

The number of individual farmers who have built their homes and who have advanced to a point where they have executed contracts for the repayment of the cost of water is upwards of 25,000. In addition there are many thousands of other farm units to which water is being brought, and which have not yet reached a point where a contract for repayment has been made, so that in counting the areas supplied outside of strictly reclamation lands, there are upwards of 30,000 farms dependent directly upon the works built under the terms of the reclamation law. Mere numbers, however mean little in this connection. We may assume that each pioneer family is composed of at least five persons—the father, mother, and two or three children or near relatives, all helping to a greater or less degree in the work on the farm; the younger or weaker members are attending to the poultry, and so on up, according to the strength, to the more vigorous man of the family doing the heavy work of plowing and putting in the crops. Thus we have a population of, say, 150,000 people, which if gathered in one locality would make a good-sized American city. This number of people is located in 25 or more separate areas, within which have grown up many

small towns in which is gathered a population equaling or exceeding that on the farms. These latter are engaged in local business, in buying and selling supplies both from and to the farms, and in transporting these. The social and political effect of this rural population is far greater than it would be if all in one locality.

These reclaimed areas have a peculiar significance and value to all industries, because they are in the midst of vast areas of grazing lands surrounding them on all sides, stretching for hundreds of miles over desert and mountains. The irrigated lands are real oases in this desert or vast extent of land with sparse vegetation furnishing some grazing which when obtainable depends upon the erratic rainfall. The cattle on these open ranges may increase rapidly throughout a series of relatively wet years, then in time of normal drought the cattle and sheep are unable to find sustenance; many herds would be completely wiped out were it not for the hay and grain obtainable at these artificial oases of reclaimed lands.

In the same way, the mines, especially of low-grade ores, and the other natural resources, become more easily available and more profitable to work because of the existence of local food supplies from the irrigated lands. The ultimate conservation and best use of the timber, grass, and minerals is thus bound up in the existence of these tilled areas. More than this, however, and most important of all, is the fact that these lands are furnishing homes and are bringing into the thinly settled arid States and maintaining there a permanent and prosperous population—one which tends to stabilize all Government and business institutions.

The example of the United States as a federal whole in embarking on work of this kind is one which stimulates the individual States to action, also many corporations and individuals, at home and abroad. The works and resulting homes have, therefore, a large significance not only to the citizens of our own country but to those of other lands; for in nearly every large country of the world are vast tracts of arid and semiarid lands which may be used ultimately for homes for the people as the population increases and as necessity is found to provide room for growth.

All of this tends toward the establishment and maintenance of world peace, in the sense that some of these nations may expand internationally and be relieved in part from the temptation of intrusion upon their neighbors, since they have within their own borders lands to be conquered—not from other men but from nature herself. This conquest is often a real warfare with nature, for in the early stages of pioneering it seemed as though every unusual or exceptional occurrence took place: Unprecedented floods, or droughts; plant dis-

eases; plagues of insects; hopping, running, jumping things of the field—grasshoppers, rats, and rabbits—everything to discourage and drive away the venturesome settler; and yet, when these difficulties are overcome and a hardy citizenship is established on the land, there is probably no part of the country where a greater reward for toil and thrift is to be found than on these reclaimed lands.

While there is a certain similarity in the investigations to be made and plans to be prepared and structures to be built, yet each locality offers its peculiar problems—not merely in engineering, but more than this in climatic, cultural, human and economic relations. The reclaimed areas of the United States vary in conditions from those somewhat tropical in character, with all-the-year-around crops, and consequent insect and plant pests, to those of the snowy North, where the short, hot summer renders possible only a single quick-growing hay, grain, or vegetable crop. Then follows the long winter which may be turned to advantage in the feeding of domestic animals.

The conservation and distribution of the water, upon which rest all land values in the arid regions, are subject to certain climatic and topographic limitations peculiar to each project. At one extreme are the erratic rivers of the Southwest, in whose broad, bowlder-strewn channels water can be found only at intervals of months, or even years. When it does occur, it may come in great cloudbursts carrying destruction. Here, the use of the dry lands is dependent upon water storage capacious enough to hold these floods. The other extremes are the steadily flowing rivers which come from the high mountains; here the amount of water is in a general way proportional to the sun's heat falling upon the snowbanks in the mountains; the regularly recurring floods of each spring vary within relatively narrow limits. Under such conditions the minimum storage may be required and other works can be built in accordance with the regular régime of the streams.

After all, the success of the undertaking is measured in terms of human relations. The making of opportunities for homes is in itself largely mechanical, and the engineering construction can not be said to be a success unless these opportunities for home-making are utilized and fully enjoyed. To have such utilization and enjoyment there must be an adaptation or a making over of a considerable number of people. The newcomers, transplanted to these new surroundings must be able and willing to adapt themselves to new ways; they must drop the methods which they learned in humid regions; their ultimate success will be measured by the quickness with which they are able to appreciate the new ways of doing things and of putting these to use.

In most of the discussions concerning the reclamation and settlement of waste lands and the building of homes upon these, most attention has been given to the mechanical side of the work. This is most picturesque and affords opportunities for more precise statements as regards methods and results of scientific investigation and of application of results of costs and of values; hence it is that most thought has been given to the large and picturesque structures, such as high dams, tunnels, and canals winding through rough country, but the real interest is in the human relations, in the kind of people who have come to inhabit the waste lands, and who, individually and collectively, must dig out from the soil the products in the way of crops which not merely support the family, but afford the materials which enter into trade and commerce, and which when sold will pay for the cost of the works.

A full review of the success of reclamation should embrace all the factors of home making and should give maximum amount of attention to the human side of the question. The fact that these matters of "life, liberty, and pursuit of happiness" can not be weighed and measured with the same degree of accuracy as can the materials for construction and the forces of nature renders such a review of the broad subject of reclamation and settlement less easy and attractive. And yet, after all, the conclusions on the human side afford the "acid test" of success.

The full extent of this success as just indicated is hardly susceptible of statistical treatment; the power of the imagination is required to fill in the most important matters—that is the moral or spiritual aspect of the case, in the stabilization of the family, and the stimulation to better citizenship which results from the ownership of a piece of land and the development of a home on it. Such development is indicated by plate 5, figure 1. In the foreground is the irrigating canal bringing water to the thirsty land, beyond it the tent first occupied by the home maker. Next to this is the cheap house, built of thin boards, standing in a desolate land, but in a land which becomes quickly transformed through the application of the water. The result of a few years of effort is illustrated in plate 5, figure 2, by the house improved and sheltered by the rapidly growing trees, surrounded by attractive shrubbery, as well as by productive fields.

In the paragraphs that follow an attempt is made to review briefly the steps taken in reclamation for homemaking, beginning with the preliminary research, continued through topographic and hydrographic surveys; followed by the planning and execution of the work; the development of the waste places—and last but not least the dealing with the human, social, and economic forces—which

must be successfully utilized to produce the desired result, namely the creation of prosperous and contented homes.

Research.—The thinking people of the country are becoming more and more impressed with the importance of thorough investigations to find out in advance of large action whether certain assumed facts are true, or what other facts should be learned in order to make a success of the undertaking. This is relatively a recent attitude on the part of the public; and in the memory of men now living there is a recollection of the extreme difficulty in securing popular support and legislative authority for any kind of investigation of national resources and opportunities. It is now almost impossible to realize the great difficulties encountered by pioneers among the scientists such as Maj. John Wesley Powell, in his efforts to induce Congress to investigate the extent to which the waste lands of the country might be utilized. He did succeed, however, after years of patient perserverence, and in 1888 was authorized by Congress to begin the work upon which has been founded the great national policy of reclamation and home-making. Methods of measurement of streams were devised under him; surveys were made of possible reservoir sites; and vast quantities of data were acquired concerning the mountain masses from which came the streams, and also of the lower-lying desert lands which might be irrigated by conserving and distributing the erratic floods which came from the mountains and foothills. This was the first great step of research in this line; it was followed by the more mechanical details of preparing plans and specifications for works to fit the conditions discovered by these surveys and examinations.

Application of research.—The facts acquired would have had little more than purely scientific value and the investigations of lands and waters would probably have been brought to an early conclusion had it not been possible to secure practical application of the results to the needs of mankind in the way of producing opportunities for small farms and homes.

This practical application of the facts obtained from research was due largely to the persistent following of the vision of human and national needs and benefits held by the late Francis G. Newlands and Theodore Roosevelt. Through their aid and that of other farsighted men there was placed on the statute books the reclamation act of June 17, 1902, which set aside funds obtained from the sale and disposal of public lands to be used in the construction of works for the reclamation of arid and semiarid land; also, incidentally, of the drainage of such of these lands as needed relief from excess water.

Building the works.—The operation of building the great structures has great popular fascination, and the work itself is susceptible of pictorial illustration; views of some of the more notable of these works have already been printed in earlier Smithsonian publications;[1] but at this time reference is made to some of the more notable advances in ways and means of overcoming obstacles. The planning and building of works of reclamation afford opportunities for a wide display of ingenuity. While the main lines of the various larger structures are to a certain extent standardized, there arises on each undertaking and in each locality new conditions which must be met. The way in which these difficulties are overcome is of interest—not only to the American engineer and constructor, but to citizens of every country who hope to see similar works built to overcome the natural obstacles of his land and to permit a larger use of the natural resources. Some of these ingenious ways are illustrated in plate 6, which, in the upper part, shows the irrigating canal carried in reinforced concrete flume along steep and crumbling hillsides, and conforming to the irregularities of the topography. In plate 6, figure 2, is shown a similar flume which has entered a deep depression. Here an inverted siphon or concrete box has been built to conduct the water down one side and up the other into the continuation of the flume.

The attempts made to utilize the fertile, but dry, lands of the country for farming and home-making have often been futile where the difficulties of obtaining water have not been successfully overcome. Plate 7 illustrates by contrasting pictures the results which have followed the attempts to settle a dry country with and without a water supply. In plate 7, figure 1, is shown a view, typical of millions of acres of good, level plow lands which are highly productive when the rains occur; these erratic rains, however, can not be predicted; they occur often at the wrong time. Attempts made to settle such lands have resulted in hardship and losses. Throughout the western part of the Great Plains region of the United States are to be seen thousands of settlers' shacks with one door, one window, and a stovepipe, similar to that shown in plate 7, figure 1. Here the family, if it actually attempted to make a home, has been alternately frozen by the winter winds or burned by the scorching summer suns, where the thermometer is over a hundred in the shade and no shade is available.

In contrast to this are the similar dry lands, so located, however, that if they could be provided with water, as shown in plate 7, figure 2, the settler's home is soon surrounded by vegetation; the prosperity resulting from crop production has enabled improvement of

[1] See articles on reclamation in Smithsonian Reports for 1903, 1904, 1906, 1910, 1915, and 1919.

1. THE IRRIGATING CANAL AND PIONEER HOME.

2. A FEW YEARS LATER; THE SHELTERED HOME.

1. IRRIGATING CANAL IN REINFORCED CONCRETE FLUME.

2. WATER IN IRRIGATING CANAL CONDUCTED ACROSS DEPRESSION BY INVERTED SIPHON.

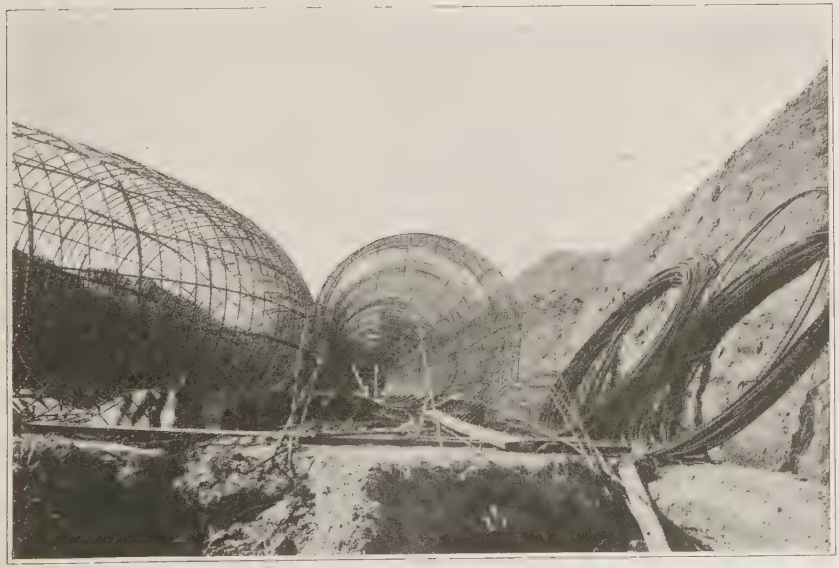
1. THE HOMESTEAD "SHACK" OF THE DRY FARMER ON THE HIGH PLAINS OF THE WEST.

2. THE HOMESTEAD MADE POSSIBLE WHERE WATER IS AVAILABLE.

1. WIND-BLOWN SAND OF THE NEWLANDS PROJECT, NEVADA.

2. IRRIGATED PORTIONS OF THE NEWLANDS PROJECT, NEVADA.

1. SILT TRAP AT HEAD OF CANAL AT LAGUNA DAM ON COLORADO RIVER.



2. STEEL REINFORCEMENT FOR CONCRETE PIPES.

1. EXCAVATION BY DRAG LINE.

2. CLEANING AN IRRIGATING DITCH WHILE IN OPERATION.

the house and the procurement of the comforts necessary for a family.

Cost and value of works.—The cost of works of reclamation must necessarily be limited by their ultimate productive value, and must be kept within such limit if reclamation is to be continued indefinitely. This value is determined by the ability of the landowners to produce and market crops at a profit. Thus the problem of the practicable cost of reclamation is one not merely of climate and soil, but, more than this, of the human factors of transportation, markets, skill, and thrift. At the present time the limit of cost, taking the country at large, may be stated as being approximately $100 an acre of land actually benefited. This is merely a convenient unit for measuring the relative cost of such enterprises and is by no means fixed nor is it an infallible guide.

The cost of reclamation as actually developed has been larger than anticipated. It was assumed in a general way when the reclamation act was passed in 1902 that considerable results could be had at, say, $30 per acre. Ten years later the limit was put at about $60 an acre, and 20 years after at about $90 per acre. Under exceptional conditions, such as those of southern California, and with high-grade fruits, a cost of several hundred dollars an acre is practicable, while on the other extreme, in Montana, $50 an acre may be a large sum. In the case of drainage alone $20 to $30 an acre may be considered as a fair standard. That is to say, for the ordinary farmer it would be unwise to incur expenditures above those which have been quoted, but they serve merely as an indication as to what may be expected or as a basis for discussion.

In considering the allowable cost or possible value of reclamation works, it must be borne in mind that the land to be reclaimed has in itself practically no value because it has no dependable productivity until certain obstacles have been removed by reclamation. The land is worth only the cost of reclamation plus the other productive improvements put upon it. If these improvements consist merely of an expensive house, barn, or other equipment, not absolutely necessary for adding to the production of the soil, the expenditures on these partly used improvements can not be considered as adding to the real value of the land. Because of failure to distinguish between real productive values and those things which are desirable but not productive, there has been much disappointment in the outcome of investments of this kind.

Geographical changes.—The work of reclamation brings about notable changes in the commercial and political geography of a region. It alters to a certain degree the topography of a country and its cultural condition by the building of large reservoirs or

artificial lakes and streams, but the largest changes are those which arise from converting a barren and almost uninhabited country into one densely populated and with villages or towns at short intervals, with trees, bird and game refuges around the lakes. The settlements are connected by highways and railroads; they are supplied with electric power, utilized not only in lighting but often in cooking and heating. The settlers have many of the conveniences which are possible in a new community in which cooperation has been highly developed.

The social or political changes are profound in that there is brought in a population attached to the soil, differing widely from the nomadic herdsmen who have previously been in possession, or the mining population which comes and goes with the discovery and exhaustion of local ore deposits. The shifting population is replaced by the most permanent known in history—that is, the tillers of the soil who are establishing homes for themselves and future generations.

Soil studies.—The works of reclamation, applying water to the soil or taking water from it, when followed by the necessary cultivation, result in far-reaching changes in the structure and productivity of the soil. It is now recognized, more than in earlier years, that the soil, or that portion which is being tilled, is not in a stable or fixed condition, but necessarly undergoes changes which are not merely mechanical or limited by the amount of water applied or abstracted. Irrigation and drainage result necessarily in bringing not only water into and out of the soil, but also in pumping, in and out, air and various gases. Many of these soil changes result in biological developments as well as chemical and physical alterations. In one sense the soil is in a continual state of change, either for better or worse, as far as plant growth is concerned.

Taking an extreme case of soil change, there may be noted that of the apparently sandy soil on portions of the Newlands project, in Nevada. While this has the structure of a loose sand, and has been thus classified, it has been found by experience that under irrigation it becomes hard and impermeable to water, so that after a few years cultivation is no longer practicable. The application, however, of certain crude chemicals, such as alum, from natural deposits not far distant, tends to increase the permeability of the soil and bring it back to a cultivable condition. These changes in soil have been discussed by Carl S. Scofield.[2]

[2] The Alkali Problem in Irrigation, by Carl S. Scofield, Annual Report of the Smithsonian Institution for 1921.

Other examples might be given, but it is sufficient here to emphasize the fact that soil surveys made prior to reclamation, while indicating the condition which prevailed at that time, must be interpreted in the light of past experience; also assumptions must be made as to what probably may take place under conditions as yet not wholly known. The soil can undoubtedly be greatly improved with proper handling, and, on the other hand, it is easily possible to destroy the value of the soil, as has been done on 10 to 15 per cent of the lands which have been reclaimed at large cost.

The changes which take place in the soil and in the character of the vegetation under irrigation may be illustrated by plate 8, which gives, in the upper part, a view across what is known as the "Forty-Mile Desert," a sandy and forbidding area on the old overland trail between Utah and California. Over this trail thousands of gold seekers have passed; many of their beasts of burden and some of the seekers themselves died of thirst on this trail. The transformation which has taken place is illustrated in plate 8, figure 2. This is not merely a change in cultural conditions; much of this so-called "sand" has been altered in texture by the application of water; some of the soil has been changed so completely as to be now almost untillable; but careful research, followed by the application of results of this scientific inquiry, are showing that these soil changes may be anticipated and met in such a way as to result in the maintenance of soil fertility.

New devices.—The problems of extension of reclamation and of home making are dependent for their solution, not only upon the careful observation and study of the facts available but also upon the development of new methods, particularly those applicable to changing conditions of soil, and the resultant effect upon the plants. The ultimate success of reclamation rests upon continually meeting and successfully overcoming the new problems of water conservation, its distribution, and the prevention of excessive use of water, resulting in alkali, or soil deterioration, and in working out feasible programs of crop or crop rotation.

Many of these problems are those related to soil erosion, the carrying in suspense and deposition of the fine mud or dirt washed from the land. Some of the river waters—notably the Colorado River of the West—are so heavily charged by the silt brought down by the river that the irrigating ditches become clogged with the sediment. Plate 9, Figure 1, illustrates one of the ingenious devices utilized to overcome this difficulty. Here the water of the river in its lower course at Laguna Dam above Yuma, Ariz., instead of being taken directly into the canal is held for a short time in a pool; the heavy material sinks in the quiet water, and the relatively clear water from

the top of the pool is allowed to flow into the head of the irrigating canal; then when the pool, or forebay, is partially filled by the silt or mud the large gates shown at the right of the picture in plate 9, figure 1, are raised and the mud is washed downstream in a few minutes; then the gates can be lowered and the mud in the water is allowed to settle.

Another engineering device, growing out of the necessity of conveying water through or across rough country, is illustrated in plate 9, figure 2, where is shown the iron skeleton or reinforcement of concrete pipes, upward of 7 feet or more in diameter. These can be built across depressions or around irregular hill slopes, and when completed carry large volumes of water under moderate pressure, and in localities where it would appear almost impracticable to build canals.

Another kind of difficulty which has given great concern in the past, but which has been overcome in reclamation work, has been the development of a machine which could excavate canals in soft or wet ground or in places where men and animals could hardly work. Such machines are illustrated in plate 10. A drag-line excavator, mounted on what is known as a caterpillar truck, is shown in plate 10, figure 1. This machine may be said to carry its own rails and to lay these down and pick them up again as the machine proceeds. Thus it can move through wet lands, where a horse would be mired, and can dig ditches under conditions which in the past have been considered almost impossible.

Still another application of science and ingenuity, overcoming obstacles which have long interfered with reclamation work, is shown in the cleaning out and maintaining of canals for irrigation or drainage while these are in use. For many years it was considered necessary, in order to clean an irrigation canal, to turn out the water and let the bottom of the ditch become dry, so that horse-drawn machines could be used. In countries where weeds and aquatic plants grow rapidly this turning out of water during the irrigation season has resulted in serious inconvenience and loss. Now, however, the problem has been solved (as shown by pl. 10, fig. 2) by a machine which traverses the banks of the canal and reaches down, digging up the weeds and dirt, depositing the material on the side, and without interfering with the flow of the water.

The conclusion of the matter is this: That the vision of benefits to the individual citizens and to the country as a whole has been shown by 20 years of experience to be a true vision. The ideals of the advocates of reclamation and home making have been realized in part; much more can be done with corresponding benefits to all parts of the Nation by increasing the stability of governmental and busi-

ness institutions, as well as increasing the supply of food and of raw materials. Nature has furnished lavishly the raw materials with which to work. Scientific research and engineering skill have still a large field of endeavor in utilizing these; but, more than all that, the human problems, those of the selection of settlers, ways of cultivation of the soil, the maintenance and increase of its fertility, the proper selection and rotation of crops, marketing, cooperative buying and selling, and particularly the social relations, should be the subject of the same kind of scientific research and of practical application of results as has been found essential in handling the engineering or material side of the problem.

Inspiration to greater work in all parts of the world comes from the realization that the dreams of the founders of the national reclamation movement have come true; that permanent communities have been established in places which 20 years ago were waste and desolate; that a high type of civilization has been extended. The imagination is stimulated to the point of attempting still greater achievements in the realization of those things which make for the increase of human knowledge and permanent prosperity.

IDEALS OF THE TELEPHONE SERVICE.[1]

A TRIBUTE TO THE MEMORY OF ALEXANDER GRAHAM BELL.

By JOHN J. CARTY,
Vice president, American Telephone & Telegraph Co. and retiring president, Telephone Pioneers of America.

This is the ninth annual meeting of the Telephone Pioneers of America, although our association is now entering its twelfth year. On account of the war, during three years no annual meetings were held. The Pioneers were then engaged in the great struggle to save civilization.

The membership of our association is made up not only from those who took part in the first development of the telephone but also from those who have been in the telephone service for a period of 21 years. We have in the service tens of thousands of zealous men and women doing pioneer work now, but because they lack in years, though not in achievement, they have not been enrolled. We and they are looking forward to the day of their formal admission. To these our fellow workers we extend our greetings and our appreciations. In their hands lies not only the future of our society but the future of our art.

Our first meeting took place 11 years ago at Boston, the birthplace of the telephone. At that meeting the inventor of the telephone, Alexander Graham Bell, was present and delivered to us an address which must always be memorable in the history of our society. To-day we recall with peculiar sadness these words which he then spoke to us:

> This is a great day for me, the first meeting of the Telephone Pioneers of America and of the world. It gives me great pleasure to meet with you all to-day, and yet there is a feeling of sadness about it. I am the first telephone pioneer, and my memory goes back to the very beginning, and I miss the faces I remember so well, the faces of the old pioneers, who I wish were here to-day. * * * I feel it a little presumptuous on my part to try to speak of the telephone to telephone men. You have all gone so far beyond me. Why, the little

[1] Presidential address delivered at the Ninth Annual Meeting of the Telephone Pioneers of America at Cleveland, Ohio, September 29, 1922. Reprinted by permission.

telephone system that I look back upon, what is it compared to the mighty system that goes through the whole extent of our country to-day? It is to you that this great telephone development is due, and I feel that it behooves me to speak very modestly of the little beginning that led to this great end. I can not tell you anything about the telephone. I can not speak to you about undulating current, intermittent current, and pulsatory current. I belong to the past; you belong to the present.

Here stand revealed those lovable qualities of the great pioneer—generosity and modesty—which endeared him to us all. It is true, indeed, that he belonged to the past, though then he still belonged to the present. Now he belongs to the ages.

Alexander Graham Bell died on Wednesday, August 2, at the age of 75, at his summer home in Nova Scotia, near Baddeck. He was buried on August 4, at sunset, on the summit of a mountain overlooking the Bras d'Or Lakes. As a tribute to his memory telephone service was suspended for one minute throughout the United States and Canada during the simple ceremony.

The manifold activities of his life, devoted to the service of mankind, would require volumes to portray. The medals and other honors which he received from learned societies, his honorary degrees from universities at home and abroad, and special recognition by governments, all testify to the esteem in which he was held. His scientific researches in the field of heredity and eugenics, his experiments in aeronautics, his work in improving the phonograph and in teaching the dumb to talk, and his invention of the photophone, reveal the scope of his mind. This record alone is enough to insure his fame, but his discovery of the method of transmitting articulate speech by electricity and his invention of the apparatus to do this have placed his name among the immortals.

Doctor Bell was born March 3, 1847, in Edinburgh, Scotland. He went to Canada in 1870, and the next year, at the age of 24, he removed to Boston. After introducing into New England schools improved methods of teaching deaf mutes to speak, he was appointed professor of vocal physiology in Boston University.

In his spare time he conducted experimental researches in electrical wave transmission. He was assisted financially in these experiments by two gentlemen of Boston, Thomas Sanders and Gardiner Greene Hubbard. By the summer of 1874 he had worked out his theory that the transmission of speech by electricity could be accomplished by producing "electrical undulations similar in form to the vibrations of the air" which accompany the original words or sounds. In spite of great difficulties and discouragements, he succeeded in reducing his theory to practical form, when, at Boston, in the summer of 1875, he invented a telephone which faintly transmitted parts of words and even entire words.

Mr. Thomas A. Watson, Bell's assistant, relates that it was on March 10, 1876, over a line extending between two rooms in a building at No. 5 Exeter Place, Boston, that the first complete sentence was ever spoken and heard through the electrical telephone. It was spoken by Bell and heard by Watson, who recorded it in his notebook at the time. It consisted of these words: "Mr. Watson, come here; I want you." Thus the telephone was born.

After completing his fundamental invention, Bell, in a remarkable document, predicted with amazing foresight the telephone system of the future. He also invented the photophone, which was the first method of transmitting speech by electricity without wires, and the induction balance and the telephone probe for which he was awarded the honorary degree of doctor of medicine by the University of Heidelberg. To his successors in the laboratories in which he was the original worker he left the further conduct of telephone research and development.

Turning to other departments of science, he displayed his remarkable intellectual gifts by the fruitful researches which he conducted. In his work on behalf of the deaf, which he continued to the end, is revealed a dominant motive in his life.

To Bell was accorded a privilege so often denied to those who have advanced the world by their discoveries—he lived to see the triumph of his great idea. When the first sentence was transmitted the public regarded the telephone as a scientific toy. Then the telephone plant of the entire world could be carried in the arms of a child. To-day vast telephone systems of intercommunication have been developed, extending the spoken word among the peoples of the nations.

The advances of the telephone art made by the successors of Bell were always a source of great satisfaction to him. Some of these, epoch making in their nature, gave him special gratification.

On January 25, 1915, the transcontinental line, spanning Bell's adopted country from ocean to ocean, was, in the presence of dignitaries of State and Nation dedicated to the public service. This was a day of triumph for Bell, for, using a reproduction of the original instrument, he once again spoke the memorable words, "Mr. Watson, come here; I want you." But this time Bell was at New York, and Watson, who heard him with perfect ease, was 3,000 miles away, in San Francisco.

Another advance attained the greatest distance over which the transmission of speech had ever been achieved. Early in the morning of September 30, 1915, words were spoken through a radio telephone at Arlington, Va., to the Hawaiian Islands, where they were plainly heard. But, as if to proclaim the telephonic conquest of

time as well as space, the words reached these distant islands of the Pacific when it was there still the evening of September 29.

There yet remained to be realized that prophetic dream of the telephone pioneers—the bridging of the Atlantic by the human voice. But the day of its fulfillment was not far off, for on October 21, 1915, during the dark days of the war, speech was for the first time in history successfully transmitted across the Atlantic Ocean. This was accomplished by the radio telephone, which carried the words spoken at Arlington to the Eiffel Tower at Paris.

The last memorable telephone development destined to occur in the life of Bell will always be associated with a great historic occasion. At the burial of the Unknown Soldier at Arlington, on November 11, 1921, the voice of President Harding, by means of the new loud speaking amplifiers, was easily heard by the great concourse of 100,000 people about him, even by those in the most distant parts of the vast cemetery. Corresponding multitudes numbered by tens of thousands, at New York and San Francisco, heard over the wires every word spoken by their Chief Magistrate as clearly as though in his actual presence. These distant multitudes heard also the invocation of the chaplain, the music and the hymns, and the words of the commitment service used by the bishop at the grave. They joined with each other and with those at the cemetery in the singing of the hymns, and they united with the President in reciting the Lord's Prayer, with which he closed his address. They heard in amazement the salvos of artillery fired at the grave, and even those on the shores of the Pacific caught the loud reverberations thrown back by the Virginia hills. At the end, in profound silence and with heads bowed in sorrow, they listened to the plaintive notes of the trumpet sounding the soldier's last farewell.

On that day the achievements of science imparted a mystical power to the most solemn national ceremony in the history of America. This ceremony, its deep significance so enriched by the art of Bell, we can now believe contained an exalted sanction of the greatest of all the achievements of his life.

These are but some of the advances which have been made in the first half century of the telephone art, which is now drawing to a close. They belong to the golden age of communications, which has achieved the extension of the spoken word throughout both space and time.

But this golden age has not yet ended, and when we contemplate the possibilities of the future we discover that it has only just begun. It is to the future that we must now turn our minds and direct our endeavors. It is true that we Pioneers belong to the past, but it is equally true that we belong to the present. As individuals, we must

all pass away, as did the first Pioneer, but our association, the Telephone Pioneers of America, will continue to live. The greatest work which our society can do is to exemplify the ideals of our service and to transmit to its future members the splendid traditions of our art. It should be our purpose to encourage and to sustain among the men and women of the telephone system their ever-increasing zeal for the public service.

While it is beyond my power to put into words these ideals of our service, they already exist within your hearts and mine, where we all can feel, though I can not express, their potency. These feelings, which form the mainspring of our actions, do not arise from mere wishful thinking, nor do they spring from an idealism which is disconnected from reality. They rest upon a solid basis of achievement and represent the practical purpose of that great telephone system of intercommunication which bears the name of our first pioneer.

It is interesting to note that the biologists were the first to appreciate the peculiar importance of electrical communications in the social organism, and to Herbert Spencer, writing more than 50 years ago, we are indebted for some analogies which have not yet been sufficiently studied either by the biologist or the engineer. In tracing the analogy between the telegraph system of his day and the nervous system of the animal organism, Spencer expressed the view that probably when the then rudimentary telegraph systems were more fully developed, other analogies would be traceable. This development has already been provided by the telephone art, and national telephone networks have now become a vital part of the social organism. I believe that the study of these networks from the standpoint of biology is destined to yield important results, and, indeed, that an investigation of the remarkable developments of the automatic machinery used in modern telephone switchboards might even throw light on the mechanism of the mind itself.

Scientists have long been studying the theory that man has advanced to his present high estate by upward progress in the biological scale from a microscopic speck of protoplasm forming the biological cell or unit of life. They have pictured him as composed of countless millions of these living creatures forming an organic entity marvelously designed, each cell performing its allotted part in that exquisite division of labor which characterizes this biological state.

We commonly compare a nation to a complex living organism. "We speak of the body politic, of the functions of its several parts, of its growth, and of its diseases, as though it were a creature. But we usually employ these expressions as metaphors, little suspecting," as Spencer says, "how close is the analogy, and how far it will bear

carrying out. So completely, however, is a society organized upon the same system as an individual being, that we may almost say that there is something more than analogy between them."

Each cell has its allotted and specialized work to do. Each cell must be fed, and live, and grow. Sustenance must be obtained, prepared, and assimilated, and the waste removed. The physiological mechanisms for doing these things, and many other things besides, have their striking counterparts in the structure of organized society, and furnish instructive material for the philosophic student. But to us of the telephone art, the most marvelous thing of all is the nervous system, that inconceivably complex communication network by which the activities of both individual and society are regulated and without which paralysis and death would result.

We are told that the cells which compose the nervous system are the latest to appear in the upward march of the organism, and that the degree of their complexity and the extent of their differentiation furnish a criterion for determining the stage of progress which has been attained. Because of the high function, almost spiritual in its nature, performed by these nerve cells, they have been called the noble cells. I have long felt and often expressed the feeling that because of this the workers in the telephone art are engaged in a high calling, building up the noble cells which constitute the nervous system of the Nation.

As in the animal body, these cells were the latest to appear, so in the structure of organized society the highest form of electrical communication, the telephone, is the latest to appear—it comes only at the stage of higher development. And again, as in the animal body, the stage of development of the nervous system is an index of its place in the evolutionary series, so I believe it will be found in any social organism that the degree of development reached by its telephone system will be an important indication of the progress which it has made in attaining coordination and solidarity.

The use of the spoken word to convey ideas distinguishes man from all other created things. The extension of the spoken word by means of electrical systems of intercommunication serves to connect the nervous system of each unit of society with all of the others, thus providing *an indispensable element* in the structure of that inconceivably great and powerful organism which many biologists feel is to be the ultimate outcome of the stupendous evolution which society is undergoing.

That such an organism, thus so magnificently conceived, would be the outcome of the higher evolution of man, I have long believed; but its form and the nature of its functioning I could not imagine. But the great work of Trotter, who has studied the gregarious

instinct in the lower animals and in man, permits us to contemplate this evolutionary entity from a new point of view. He has pointed out that nature, having failed in her giant organisms, in which so many individual cells were crowded into such animals as her giant lizards and the mammoth and the mastodon, was to try a new method which was to dispense with gross physical aggregations of cells combined into one body. He points out that the flock, the herd, the pack, the swarm—new organizations—were to be devised by nature, and to flourish and range throughout the world, and that in one of these new organizations, human society, the individual man is still to be regarded as the unit, but not constrained as is the cell in the animal body, but free to move about, the mind alone being incorporated into the new unit by the marvelous power of intercommunication. He shows that the power of these organisms depends on the capacity for intercommunication among their members, and that this power expands until the limits of this intercommunication are reached.

How fundamental electrical communication systems are in the tremendous evolution of the human race which is now being manifested in the organization of society, and how vital to the welfare of mankind is the daily work of telephone men and women everywhere is being made more and more apparent by the discoveries of the new school of biologists.

Speaking always of communication in its broadest meaning,[2] but emphasizing the importance of speech, Trotter says: "The capacity for free intercommunication between individuals of the species has meant so much in the evolution of man, and will certainly come in the future to mean so incalculably more, that it can not be regarded as anything less than a master element in the shaping of his destiny."

And again, in speaking of human society as a gregarious unit, he says: "The ultimate and singular source of *inexhaustible* moral power in a gregarious unit is the perfection of communion amongst its individual members."

As long as intercommunication was limited, he tells us, the full possibilities of nature's new experiment were concealed. But at length appeared man, a creature endowed with speech, in whom this capacity for intercommunication could develop indefinitely. "At once a power of a new magnitude was manifest. Puny as were his individuals, man's capacity for communication soon made him master of the world. * * * In his very flesh and bones is the impulse towards closer and closer union in larger and larger fellowships.

[2] In this should be included all methods of communication based upon speech, such as newspapers, books, and letters, depending upon mechanical transportation; and telegrams, depending upon electrical transmission.

To-day he is fighting his way towards that goal, fighting for the perfect union which Nature has so long foreshadowed, in which there shall be a complete communion of its members, unobstructed by egoism or hatred, by harshness or arrogance or the wolfish lust for blood. That perfect unit will be a new creature, recognizable as a single entity; to its million-minded power and knowledge no barrier will be insurmountable, no gulf impassable, no task too great." [3]

Here we have portrayed the forward march of humanity toiling ever onward to attain its goal. The realization that their wonderful art is destined to play such an important part in this final attainment opens up a never-ending source of power and inspiration for telephone men and women everywhere. It adds new dignity to their calling. Already, as we have seen, the human voice has been carried with the speed of light across the Atlantic Ocean, and across our continent, and far out into the Pacific, but still greater things are to come.

It is the mission of the Pioneers and their successors, and their associates among all the nations, to build up a telephone system extending to every part of the world, connecting together all the peoples of the earth. I believe that the art which was founded by Alexander Graham Bell, our first Pioneer, will provide the means for transmitting throughout the earth a great voice proclaiming the dawn of a new era, in which will be realized that grandest of all our earthly aspirations—the brotherhood of man.

[3] Instincts of the Herd in Peace and War.—W. Trotter.

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